Construction Scheduling Issues for Agricultural Buildings

Undergraduate Honors Research Project

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3 March 2000

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Section 1: Contractor Perspective

Abstract

The authors evaluated problems and practices in construction scheduling from the perspectives of contractors. Information about general and agricultural construction scheduling was collected via mail surveys. To determine which schedule-related factors affect on-time performance of builders, we conducted three analyses: regression, simple odds ratio, and logit. Based on the results of these analyses, we concluded that two schedule-related factors definitely improve on-time performance: the scheduler has experience as a superintendent, and the contractor provides a finish date in advance. Two schedule-related factors probably improve the odds of on-time performance: the scheduler uses past projects as resources, and the contractor provides milestone dates in advance. Eight factors may affect on-time performance: an individual person is responsible for scheduling, the scheduler has formal training, the scheduler has a college education, the contractor provides a start date in advance, the scheduler includes float time to allow for delays, the scheduler uses computer programs as resources, the scheduler uses books and manuals as resources, and the scheduler has experience as a project manager.

I. Introduction

Construction scheduling is the process of setting up a timeline for construction of a building. The construction schedule serves as the principal guideline for execution of the project, making scheduling a very important aspect of any construction project (Clough and Sears, 1991). Some examples of scheduling methods include bar charts, velocity charts (S-curves), line of balance charts, and network diagrams (Fisk, 1997). Each scheduling method has advantages and disadvantages, and the method used will be different depending on the project (Rity, 1994). Resources that are commonly available are oriented towards commercial and industrial construction (Anon., 1992, Anon., 1996, Iavarone, 1986, Kiley, 1997, Hutchings, 1996).

Scheduling is a very important aspect of any building project because scheduling mistakes can affect the costs and labor required for building the structure. The current literature on scheduling pertains mostly to the use of specific scheduling tools. Little

information is available that presents a broader perspective on construction scheduling and on-time performance. *On-time performance* here represents the percentage of projects that are completed on or ahead of schedule. *On-time project completion* represents whether or not the project was completed on schedule. This study examined problems related to construction scheduling and had the following objectives:

(1) to evaluate problems in construction scheduling as perceived by both the contractor and the customer, with special application to a subset of the industry – agricultural construction;

(2) to evaluate current practices geared toward addressing these problems;

(3) to use these findings as a guide for future work in construction.

This report summarizes our findings from a survey of building contractors. A separate, parallel report summarizes our analyses of customer perspectives.

II. Information Collection

A contractor survey was developed to collect information about the scheduling practices of companies conducting business in Ohio. Based on the survey results, statistical analyses determined which schedule-related factors, if any, affected the on-time performance of a company. The survey was mailed to 189 companies in Ohio, Indiana, and West Virginia. Those who received the surveys were primarily identified by using past Buckeye Rural Builders' (now called Buckeye Frame Builders Association) mailing lists, as well as other builder listings. Sixty-one surveys were returned. Of these, 48 were complete and valid for use in the study. A number of the invalid surveys were received from companies that were not directly involved in constructing buildings, such as engineering firms and suppliers. Additional qualitative information was obtained through personal visits with a few survey respondents.

III. Data Description

The contractor survey collected data about (1) general information about construction companies, (2) general construction-scheduling practices, (3) agricultural construction-scheduling practices, and (4) specific scheduling practices for machine shops and livestock buildings. Responses were based on construction projects that were completed within the

past two years. Appendix A is the survey as mailed to builders and Appendix B contains a summary of the survey responses.

A. General Information

The first section provided general information about the construction companies. Each contractor reported the number of employees and crews, annual sales, and number of projects completed. The following indicators were determined from this information: sales per employee, sales per crew, projects per employee, and projects per crew. Each contractor also gave a breakdown of the types of construction projects completed annually on a percentage basis. Finally, the builder indicated whether premanufactured buildings were used.

B. General Scheduling Information

The second section of the contractor survey provided information about company scheduling practices. The contractors responded to the following: (1) whether an individual employee or department is responsible for scheduling; (2) the training and level of experience of the scheduler; (3) the relative number of projects that were completed ahead of schedule, on schedule, and behind schedule; (4) whether or not they provide start dates, finish dates, milestone dates, and/or an itinerary to their customers; and (5) the frequency of use of scheduling incentives or penalties used in projects.

Contractors indicated the level of scheduler training by selecting one or more of three categories: formal, informal, and on-the-job. Those contractors who selected formal training also chose one of three more specific responses: college, technical school, or company classes. Contractors indicated the level of previous construction experience of the scheduler by selecting one or more general positions: laborer, superintendent, project manager, estimator, none, or other.

C. Agricultural Scheduling Information

The third section of the contractor survey provided information about agricultural construction scheduling. First, contractors described scheduling resources and approaches that are specific to agricultural construction. Second, they reported how often they use labor

and subcontractors that are supplied or specified by customers. Third, the contractors rated the likelihood of several events or circumstances affecting agricultural construction projects. These events or circumstances included inclement weather; equipment problems; labor availability; material availability; interaction, or lack thereof, with customers; subcontractor delays; and approval of permits, inspections, and plans. Fourth, the contractors indicated their company's on-time performance for agricultural building projects, just as in the general scheduling information section. Finally, builders described steps they have taken to improve scheduling accuracy for agricultural projects.

D. Specific Scheduling Practices

The final section of the survey provided information about scheduling for two specific types of buildings: machine shops and buildings for housing livestock. First, contractors gave the likelihood of using a schedule for each type of building and described what methods they normally used. Second, the contractors described the effects of various building features on scheduling. Finally, contractors identified the relative number of buildings of each type that were based on either standard or custom plans.

IV. Methodology and Analysis

The effects of scheduling practices on on-time performance and on-time project completion were analyzed statistically. The statistical analyses focused on data from the first two sections of the survey. The data from the survey were tabulated in a spreadsheet. Numerical responses were entered directly. Ones and zeros were used, respectively, for "yes/no" questions. For choice questions, a zero was used if the response was not marked and a one was used if the response was marked. Finally, an input file that contained only numerical data was produced for use with the statistical analysis programs.

The statistical package SAS was used to perform three types of statistical analyses: (1) multiple regression analysis, (2) simple odds ratios, and (3) logit analysis. In the regression analysis, the dependent variable was "On-time". The value of this variable ranged from zero to ten and indicated the number of projects, out of ten, that were completed on time by a builder. The simple odds ratio analysis and logit analysis required a binary dependent variable, so modified values of "On-time" – using binary values (0,1) instead of

discrete values (0-10) – were used and referred to as "On-time comp." Responses that were less than 8 were assigned a value of 0, and responses equal to or greater than 8 were assigned a value of 1. Here an assumption was made that completion of 80-100% of projects on time was acceptable or desirable, while less than 80% was unacceptable or undesirable. In each analysis, the responses for completion of building projects ahead of schedule and on schedule were combined to simply represent completion on time.

Multiple regression was performed first. A stepwise regression analysis determined the significant factors that affected on-time performance. Then, a backward elimination confirmed the results. An advantage of multiple regression is that it identifies several variables that are significant. Moreover, interpretation of the results is simple and intuitive. A disadvantage of this analysis is that the additive effects of multiple variables must be interpreted conservatively.

The second analysis used simple odds ratios. The dependent variable was crosstabulated against each independent variable one at a time to determine the odds ratios. By determining odds ratios, one can determine the improvement of the odds for on-time completion due to the effect of any given independent variable. An advantage of this analysis is that it is very simple and intuitive. Its disadvantages are that it tests only one independent variable at a time and cannot test for level of confidence.

The third type of statistical analysis used was logit. Independent variables were tested until an optimum combination resulted. The advantages of this analysis are that it handles multiple independent variables, it is specifically designed for binary dependent variables, and it is very discriminatory in that it identifies a small number of statistically significant variables. Important variables that are identified as being significant in other tests may not be significant in logit analysis, so there is the potential of being overly selective, especially if it is used as the only method of analysis.

V. Results and Discussion

A. Survey Results – General Information and General Scheduling Information

The results of the first two sections of the scheduling survey provided numerical results and written comments for use in the analysis and to gain additional insights. Figure 1

shows the types of construction performed on an annual percentage basis by the survey respondents. The highest percentage is for commercial/industrial construction, 48%. Agricultural construction accounts for 31% of projects. Table 1 summarizes numerical data about the contractors.

Figure 1. Types of Construction Performed by Respondents

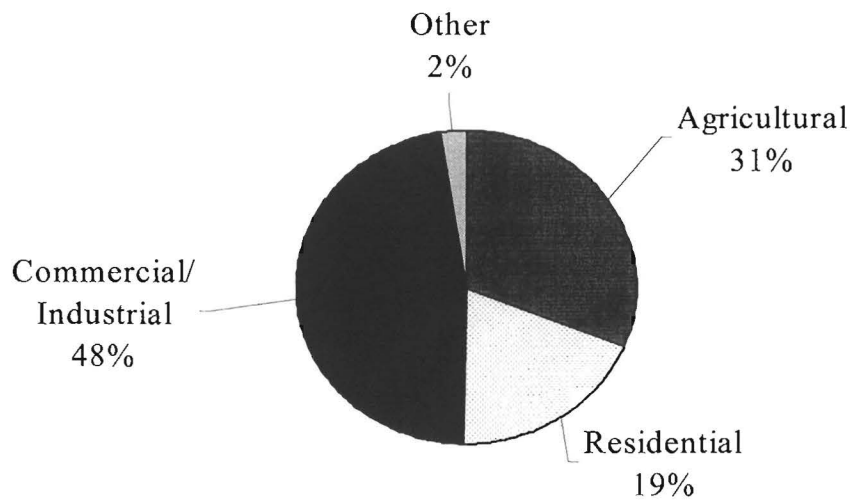


Table 1. General information about the 48 construction companies that responded to the contractor survey

Variable	Minimum	Maximum	Average	Standard deviation
Employees	1	560	28	80
Crews	0	12	3	2
Annual sales	$200,000	$120,000,000	$5,600,000	$18,000,000
Sales per employee	$29,000	$875,000	$206,000	$161,000
Sales per crew	$188,000	$6,700,000	$913,000	$1,100,000
Projects per year	4	225	47	44
Projects per employee	0.1	50.5	5.7	8.3
Projects per crew	1.7	75.0	17.1	14.0

Figure 2 shows that 25% of the responding contractors had a scheduling department and 89% of contractors had an individual responsible for scheduling. Some names of departments responsible for scheduling included scheduling, sales, coordination, and project development. Common titles of individuals responsible for scheduling included project manager, owner, president, superintendent, and estimator.

Figure 2. Scheduling entity utilized by contractors

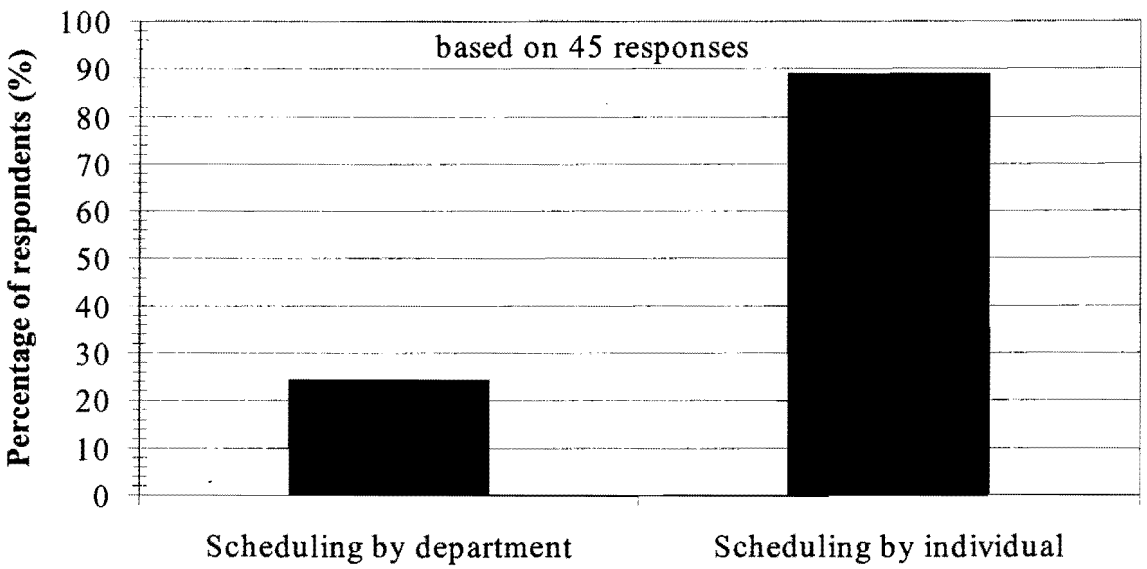


Figure 3 summarizes the responses for level of scheduler training. On-the-job training was utilized by the most companies (92%). Company classes were utilized by the fewest number of companies (2%). Formal education, which includes college, technical school, and company classes, was utilized by 17% of the companies.

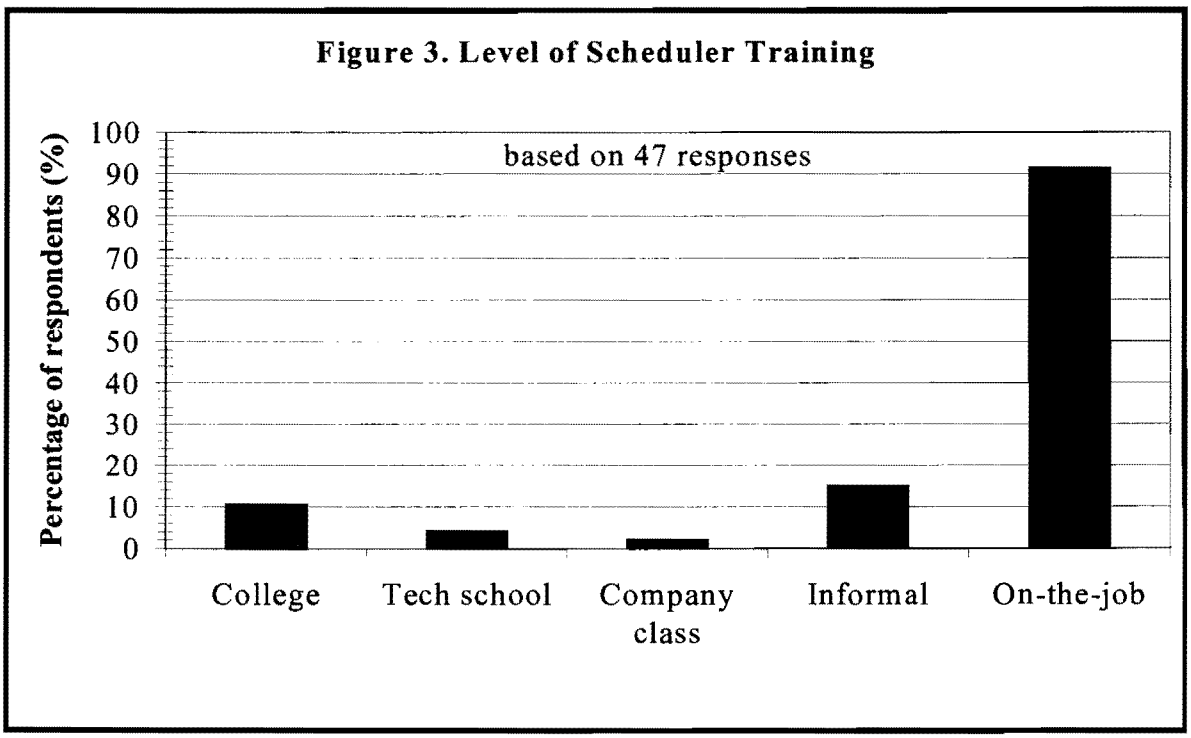


Figure 4 shows that the level of experience that is most common is project manager (76%). No construction experience was the least common (2%). Other construction experience specified included owner, salesman, and engineer.

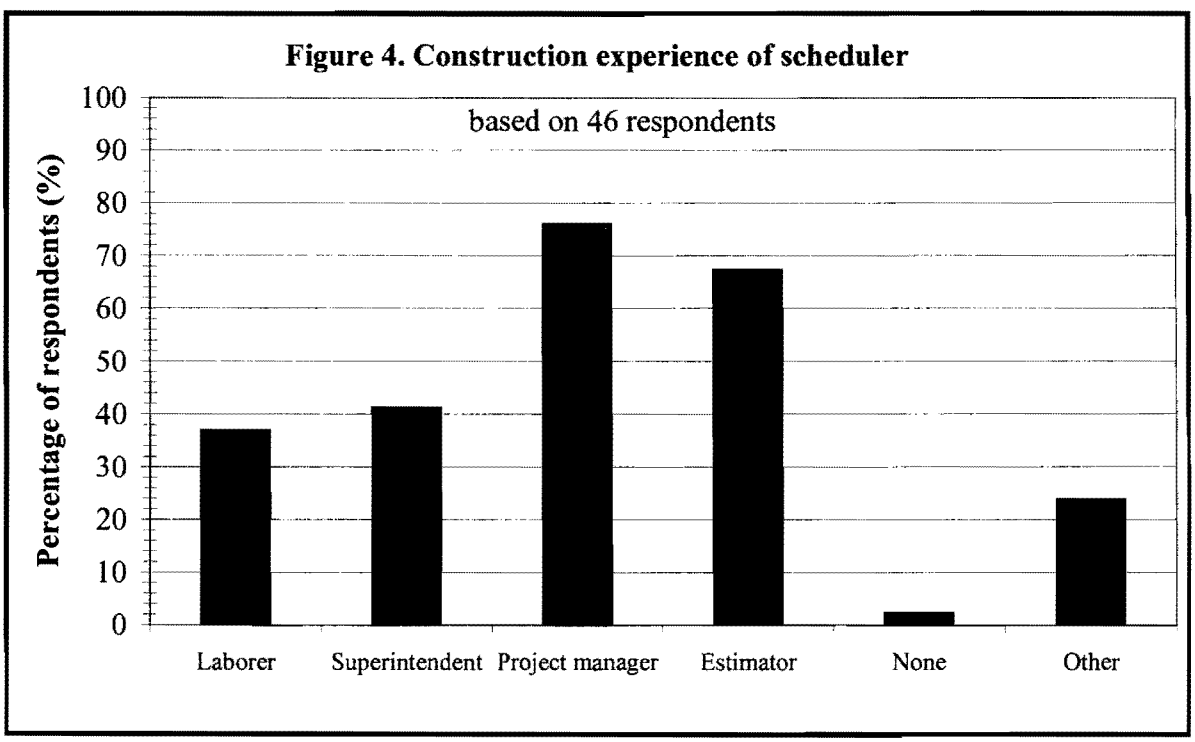


Figure 5 shows the resources that were used to assist companies in scheduling. Past projects were used by the highest percentage of respondents (83%). Methods other than those specified were used by the lowest percentage of respondents (11%). Other methods specified included input from subcontractors, time available, and common sense.

Figure 5. Resources used to assist in scheduling

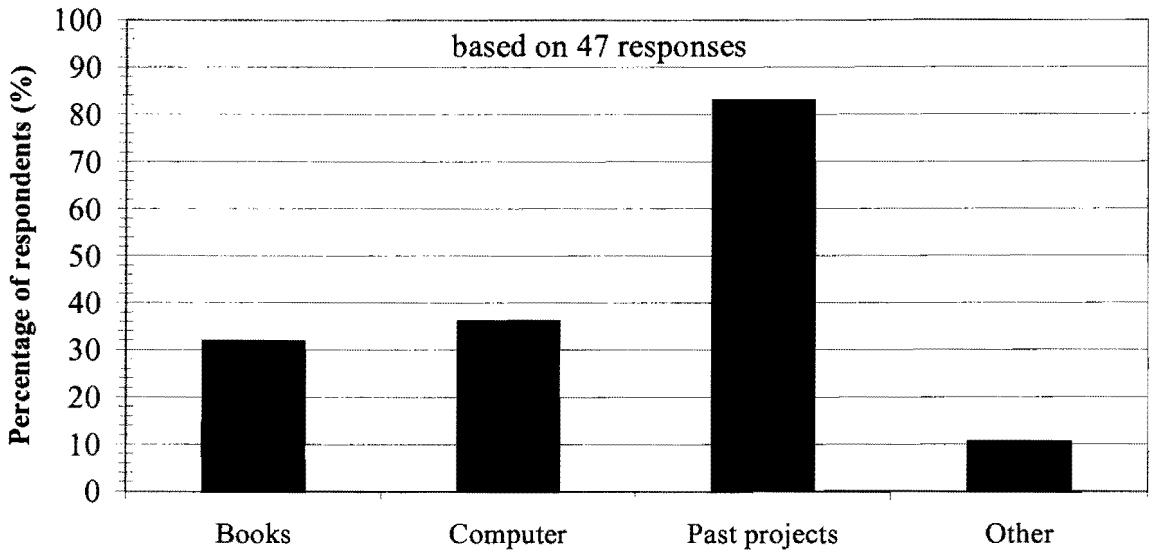


Figure 6 shows the scheduling methods used by contractors to allow for delays. The method used by the highest percentage of contractors was conservative time estimates (65%). Other methods specified included: plan to lose one day per week, draw upon past experience, and adjust for season, subcontractors and other expected delays.

Figure 6. Scheduling method used to allow for delays

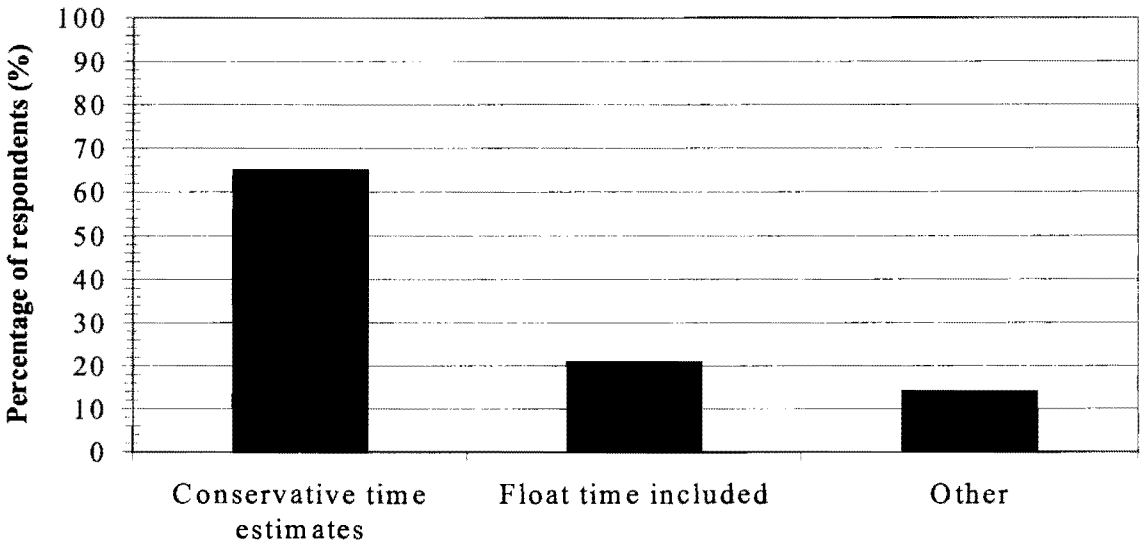
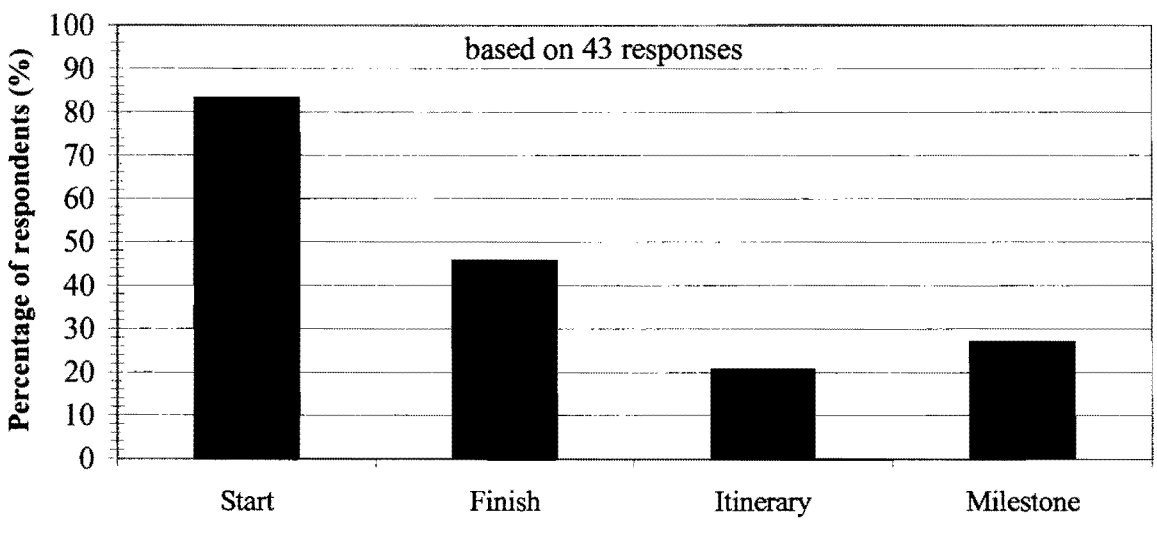


Figure 7 shows the comparative use of scheduling dates that contractors provide before construction begins. Start dates were provided by the highest percentage of contractors (83%). An itinerary was provided by the lowest percentage of contractors (21%).

Figure 7. Schedule-related dates that contractors provided in advance



The average response for the number of projects that include schedule-related incentives or penalties written into the contract was 0.5 projects out of 5. The incentives or penalties were generally financial incentives for early completion or financial penalties for each day past the completion date.

The relative number of projects that were completed ahead of schedule, on schedule, or behind schedule are summarized in Table 3. The numerical value represents the number of projects out of 5 for each category. The average was 1.2 for ahead of schedule, 2.6 for on schedule, and 1.2 for behind schedule.

Table 3. On-time performance of construction companies responding to survey

Performance level (out of every 5 projects)	Average	Share of total (%)
Projects completed ahead of schedule	1.2	23.5
Projects completed on schedule	2.6	52.7
Projects completed behind schedule	1.2	23.8
Total	5.0	100.0

Respondents also described consequences of scheduling errors to their companies. Common responses included adverse effects on profits and cash flows, customer dissatisfaction, damaged reputation, and overtime and crew stress.

B. Statistical Analysis

Table 5 provides an explanation of each of the response variables collected and used in the statistical analysis. Table 6 provides an explanation of each of the response variables that were collected for information only. Table 7 shows which variables influenced on-time performance and were significant at the 15% confidence level (where applicable). The 15% confidence level was selected because it provided a reasonable level of statistical confidence for the nature of the data and was readily applied across the three analyses.

Table 5. Explanation of variables used in analyzing data from the contractor survey

Variable name	Explanation	Response type	Survey question number
Dependent variables			
On-time	Number of projects completed on or ahead of schedule	Number out of 5	11
On-time comp.	Project is completed on time	Derived	11
Independent variables			
Premanuf.	The company uses premanufactured buildings	Yes/no	6
Department	Scheduling department is responsible for scheduling	Choice	7
Individual	Individual is responsible for scheduling	Choice	7
Formal training	The scheduler has a formal education (college, technical school, or company classes)	Choice	8
College	The scheduler has received college education	Choice	8
Tech school	The scheduler has received technical school education	Choice	8
Company class	The scheduler has received training through company classes	Choice	8
Informal	The scheduler has received informal training	Choice	8
On-the-job	The scheduler has received on-the-job training	Choice	8
Laborer	The scheduler has experience as a laborer	Choice	9
Superinten-dent	The scheduler has experience as a superintendent	Choice	9
Project mgr.	The scheduler has experience as a project manager	Choice	9
Estimator	The scheduler has experience as an estimator	Choice	9
None	The scheduler has no construction experience	Choice	9
Other exp.	The scheduler has other construction experience	Choice	9
Books	Books are used as a scheduling resource	Choice	10
Computer	Computer programs are used as a scheduling resource	Choice	10
Past projects	Past projects are used as a scheduling resource	Choice	10
Other res.	Other scheduling resources are used	Choice	10
Conserva-tive	Conservative time estimates are used to allow for delays	Choice	12
Float	Float time for non-critical tasks is used to allow for delays	Choice	12
Other delay	Other methods are used to allow for delays	Choice	12
Start date	The contractor gives a start date	Choice	14
Finish date	The contractor gives a finish date	Choice	14
Milestone date	The contractor gives milestone dates	Choice	14
Itinerary	The contractor gives an itinerary	Choice	14
Penalty	Percent of projects that included schedule-related incentives or penalties	Number out of 5	15

Table 6. Explanation of variables used for information only from the contractor survey

Variable name	Explanation	Response type	Survey question number
Employees	Number of employees	Numeric	1
Crews	Number of crews	Numeric	2
Sales	Annual sales (based on previous 2 years)	Numeric	3
SPE	Sales per employee	Calculated	1,3
SPC	Sales per crew	Calculated	2,3
Projects	Annual number of projects (based on previous 2 years)	Numeric	4
PPE	Projects per employee	Calculated	1,4
PPC	Projects per crew	Calculated	2,4
% Ag.	Percent of projects that are agricultural construction	Percentage	5
% Resid.	Percent of projects that are residential construction	Percentage	5
% Comm.	Percent of projects that are commercial construction	Percentage	5
% Ind.	Percent of projects that are industrial construction	Percentage	5
% Other	Percent of projects that are other type of construction	Percentage	5

Table 7. Scheduling factors of on-time performance (significant variables by statistical analysis); (+ denotes positive effect, - denotes negative effect)

Variable	Regression analysis	Simple odds ratios	Logit analysis
Superintendent	+	+	+
Finish date	+	+	+
Past projects	+	+	
Milestone date		+	+
Individual	+		
Start date	+		
Formal training		+	
College		+	
Float		+	
Computer		+	
Books		+	
Project manager		+	
Other resources		-	
Premanuf.		-	
Department		-	
Conservative		-	

1. Regression Analysis

The results of the regression analysis (Table 8) showed that five factors affected on-time performance (On-time): Individual, Start date, Past projects, Superintendent, and Finish

date. Each of these variables had a p-value lower than 0.10, with Start date having the lowest (about 0.05). The effects of variables that were not significant are summarized in Appendix C.

Table 8. Regression analysis results for statistically significant ($p \leq 0.15$) factors of on-time performance

Variable	Parameter estimate	p-value
Individual	1.839	0.061
Start date	1.340	0.050
Past projects	1.052	0.099
Superintendent	0.951	0.066
Finish date	0.863	0.092

The results of the regression analysis showed that five of the variables affected on-time performance. The magnitude of the effect of each variable can be determined using the parameter estimate. The parameter estimate indicates the level of improvement of average on-time performance that resulted from each variable compared to the average for the sample. For example, the parameter estimate for Individual is 1.84. This means that if an individual was responsible for scheduling, the average on-time performance was approximately two projects out of every ten higher than the average for the sample.

The first factor was whether or not an individual employee schedules projects, as opposed to a scheduling department. This result seems reasonable, especially if that individual was responsible only for scheduling and had extensive experience. On the survey form, contractors reported the titles of the individuals who scheduled projects and a common response was the president or owner of the company. Since an owner or president probably has significant construction experience, he or she should have a better-than-average basis for scheduling projects.

The second significant factor was the provision of start date before a project begins. Providing the customer with a start date indicates that a contractor probably has a plan to mobilize and begin construction. It shows the contractor's commitment to starting, and hopefully completing the project on time.

The third significant factor was the use of past projects as a scheduling resource. Lessons learned from past projects can be incorporated into the scheduling of future projects, which should improve on-time performance if done consistently over time. In addition,

when a contractor has constructed several buildings that are similar in size and scope, scheduling should become more accurate for subsequent projects of similar nature.

The fourth significant factor was a scheduler's experience as a superintendent. A superintendent works in the field, overseeing the daily activity on construction sites. This background should be very valuable in scheduling; not only for determining durations of activities, but also for coordinating activities.

The fifth significant factor was the provision of a finish date before a project begins. Providing a finish date suggests that a contractor probably has established a plan for completing the project on schedule, which should result in better on-time performance. Also, a project may stay on schedule because the company wants to avoid not meeting the completion date and facing the possible repercussions.

2. Simple Odds Ratios

The results of the simple odds ratio analysis (Table 9) showed that ten factors positively affected the odds of on-time project completion (On-time comp.) to a noteworthy degree: Float, Finish date, Individual, Superintendent, Computer, Books, Formal training, Past projects, Project Manager, and Milestone date. Each of these variables had a simple odds ratio higher than 2.0, with Float having the highest. The results also showed that four factors negatively affected the odds of on-time project completion to a noteworthy degree: Other res., Premanuf., Department, and Conservative. Each of these variables had a simple odds ratio less than 0.5 and higher than zero, with Conservative having the lowest.

Table 9. Odds ratios for improving on-time completion

Variable	Simple odds ratio	Logit odds ratio	Logit p-value
Float	999*		
Finish date	15.40	16.949	0.030[a]
Individual	6.00		
Superintendent	4.25	9.524	0.055[a]
Computer	3.21		
Books	2.54		
Formal training	2.41	0.126	0.431
Past projects	2.33	0.334	0.517
Project mgr.	2.29		
Milestone date	2.20	17.241	0.066[a]
Other delay	1.61		
Itinerary	1.43		
College	1.25		
Start date	1.00	0.334	0.413
Laborer	0.92		
Penalty	0.89	0.853	0.844
Other exp.	0.79		
Informal training	0.73	12.508	0.344
Estimator	0.72		
Other res.	0.41		
Premanuf.	0.35		
Department	0.26		
Conservative	0.15		
On-the-job	0**	999	0.977
Tech school	***		
Company	***		
None	***		

*A simple odds ratio of 999 indicates there were no affirmative responses for the independent variable that corresponded to projects being completed behind schedule.

**A simple odds ratio of 0 in this case indicates there were no respondents who did not use on-the-job training who had projects being completed behind schedule.

***Indicates there were insufficient affirmative responses for the independent variable overall to justify doing any statistical analysis.

[a]Indicates the variable was significant at the $p \leq 0.15$ level.

The numerical value of each odds ratio provides an indication of the improvement in the odds of achieving on-time project completion through the implementation of that particular variable. Variables with odds ratios greater than 1.0 demonstrated improvement in the likelihood of on-time project completion and vise versa. A sample odds ratio table and

explanation are provided in Appendix D. In this study, the odds ratio for Formal training was 2.4. This means that the odds of on-time project completion improved by a factor of 2.4 when the scheduler had formal education or training in this area. Therefore, if the odds of attaining on-time project completion when a typical scheduler has no formal education are 5:3, then the odds for schedulers having a formal education should be 12:3. The improvement in odds is multiplied directly.

Of the ten factors found to improve the odds of on-time completion, four were described previously: an individual employee schedules projects, the use of past projects as a scheduling resource, the scheduler's experience as a superintendent, and provision of a finish date in advance of construction. The fifth factor was including float time when scheduling a project. Float time is extra time in a construction schedule for completion of tasks that are not critical to the overall project. If float time is included, delays in the completion of certain activities will not negatively impact completion of the building project.

The sixth factor was using computer programs as resources for scheduling. Computer resources could include scheduling programs, and estimating programs that have capabilities to work with scheduling programs. While human judgement is still required for scheduling accuracy, computer programs can make the process more efficient. Databases can be developed with man-hours and durations for specific activities. This should improve scheduling accuracy and on-time performance.

The seventh factor was using books and manuals as resources for scheduling. These could include books that describe the procedure of scheduling, books that provide technical information about specific construction processes, or manuals that give man-hours required for tasks. All of these examples would be useful in developing a schedule and improving on-time performance.

The eighth factor was formal training of the scheduler. In these analyses, formal training included college, technical school, and company classes. Intuitively, any training should improve a scheduler's abilities, resulting in improved on-time performance. A college education may provide broader and more intensive training in project management, scheduling, and other related subjects.

The ninth factor was the scheduler's experience as a project manager. A project manager coordinates all aspects of an ongoing construction project. This experience should

be beneficial for scheduling, especially in coordinating the overall project and knowing where delays might occur, in the field and administratively.

The tenth factor was the provision of milestone dates in advance. Milestone dates provide intermediate deadlines throughout a project. If a contractor provides these dates to a customer, it reflects advance planning. The establishment of milestones also provides a contractor regular opportunities to evaluate progress during construction. Changes can be made in construction activity to get projects back on schedule, if necessary.

There were also four factors that negatively affected the odds of on-time project completion compared to the average for the sample. These factors may not be as effective for achieving on-time performance. The first factor was the use of other resources, besides books, computer programs, and past projects, for scheduling. The input from subcontractors may have been inadequate, the time available may have been incorrect, or common sense alone may have been ineffective.

The second factor was the use of premanufactured buildings. This was a bit unexpected, because it seems the use of premanufactured buildings would result in an improvement in odds of on-time project completion due to efficiency of construction. It is possible that companies had reduced expected time durations for projects involving premanufactured buildings too much.

The third factor was a department was responsible for scheduling. This could occur if each employee within the department has a different method for scheduling. Such inconsistency could lead to scheduling inaccuracies and poor on-time performance. The department might also have responsibilities in addition to scheduling. This could result in employees not focusing on scheduling sufficiently. This could also occur as a general result of working as part of a group. In some settings, such as a department within a company, where the group is accountable for its performance, individuals may not put in as much effort to excel as they would if they were more directly accountable.

The fourth factor was the use of conservative estimates to allow for delays. The use of conservative time estimates for projects would involve including more time for activities. It is possible that the scheduler's perception of conservative time estimates may not be sufficient, resulting in decreased odds of on-time performance. Another explanation could be

that the workers and subcontractors in the field know that the schedule is conservative so they do not work as quickly.

3. Logit Analysis

The results of the logit analysis (Table 9) showed that three factors affected on-time performance: Superintendent, Finish date, and Milestone date. Each of these variables had a p-value lower than 0.10, with Finish date having the lowest.

The magnitude of the effects of each variable can be determined by using the odds ratio. The odds ratio from the logit analysis is interpreted in the same way as the simple odds ratio described previously. The difference between the simple odds ratio and the logit odds ratio is that the effects of the logit odds ratios are multiplicitive (Appendix D). In this analysis, the odds ratio for Superintendent was approximately 9.5 and, for Finish date, 17. This means that if a scheduler had experience as a superintendent, the odds of achieving on-time completion were improved by a factor of 9.5 compared to the odds ratios of schedulers who had never been a superintendent. If a finish date was also given in advance, odds of on-time project completion improved by an additional factor of 17.

The logit analysis resulted in the fewest significant variables — three: the scheduler's experience as a superintendent, provision of a finish date, and provision of milestone dates in advance of construction. Because this was the most discriminative analysis, we considered these variables to be very important. They were also significant in one or both of the other analyses, which further supported their importance for on-time performance. Several variables were eliminated early in the logit analysis, due to poor p-values. Because of the nature of the analysis, and the lack of statistical significance no conclusion can be made about the effects of these variables.

4. Scheduling performance and profitability

The effect of on-time performance on a company's gross sales was also analyzed statistically. In this analysis, the dependent variables were sales per employee (SPE) and sales per crew (SPC). These values were used as a potential indicator of profitability, as opposed to actual sales, so that all companies could be compared. "On-time" was the independent variable. The results of this analysis (Table 10) showed that the effects of on-

time performance on SPE and SPC were not statistically significant. However, the parameter estimates indicate a positive effect. For example, the parameter estimate for on-time performance in the test with sales per employee is 7,415. This means that if the on-time performance increases by one project out of ten, the sales per employee might increase by approximately $7,415. Further work in this area may determine whether there is a significant relationship between on-time performance and profitability of a company.

Table 10. Regression analysis results for on-time performance as a factor of sales per employee and sales per crew

Dependent variable	Parameter estimate	p-value
Sales per employee	7,415	0.683
Sales per crew	58,346	0.640

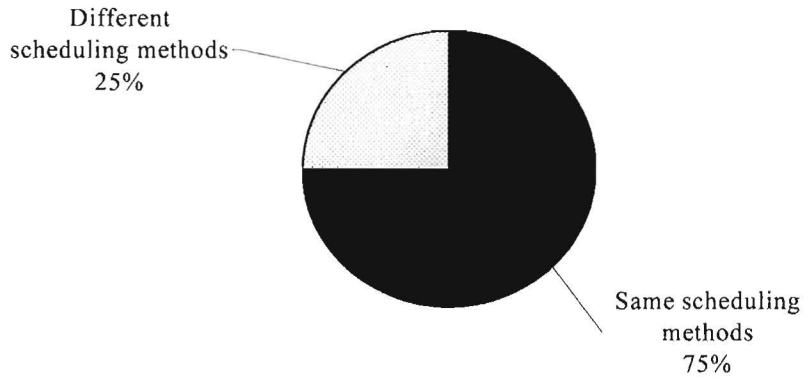
C. Survey Results -- Agricultural Scheduling Information and Specific Scheduling Practices

Responses from the agricultural scheduling information and specific scheduling practices sections provided information specific to agricultural construction. This information was used to determine the differences in on-time performance for agricultural construction, if any, and the causes of these differences.

Respondents gave examples of scheduling resources they use that are specific to agricultural construction. These included past experience, computers, and agricultural markets and seasons. Also mentioned were the College of Food, Agricultural, and Environmental Sciences at The Ohio State University, and the National Frame Builders Association (NFBA).

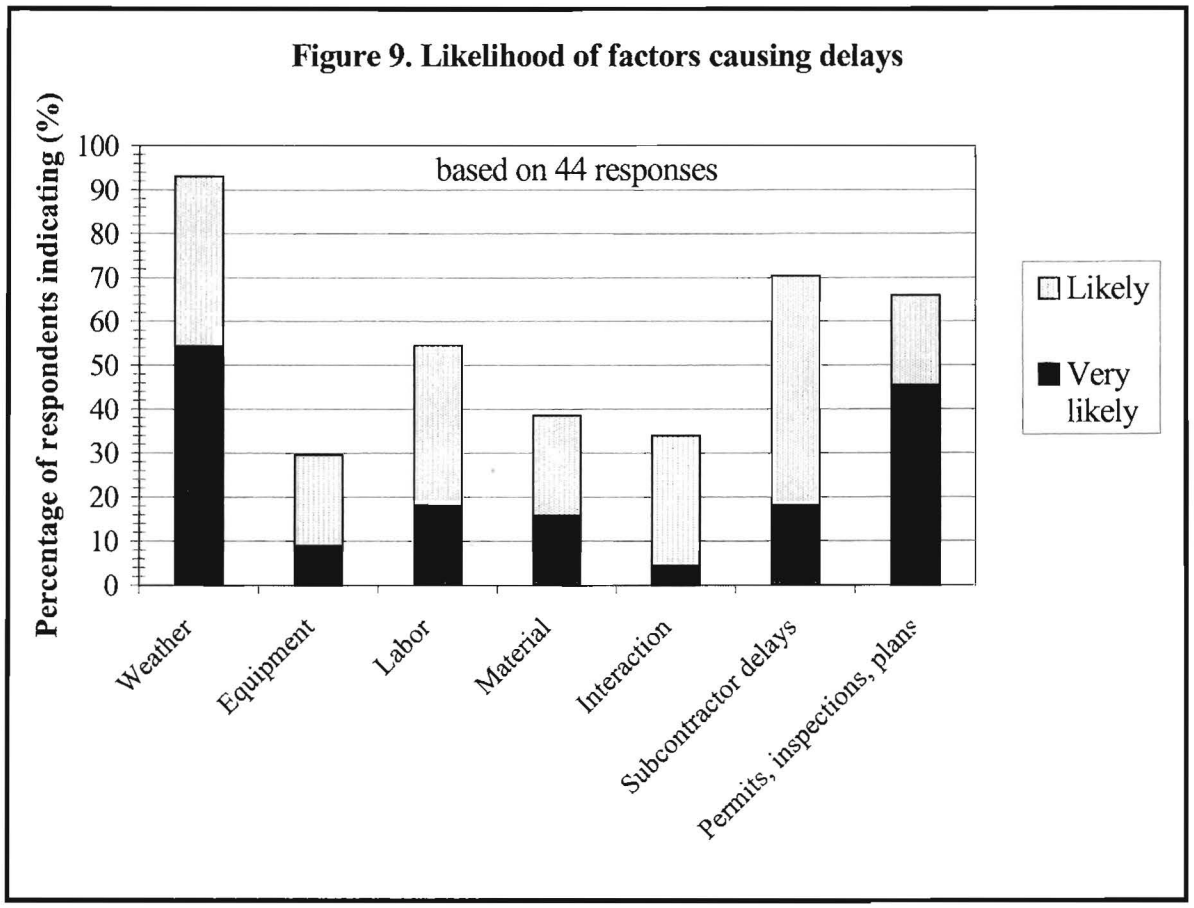
Figure 8 shows that 75% of respondents use the same scheduling method on agricultural projects as on general projects while 25% use different methods. Those who do not use the same method described what determines the method that will be used. Specific comments included the size, scope, and complexity of the project, site conditions, season, and past experience.

Figure 8. Use of same scheduling method for all agricultural projects



Respondents also described occasions when there would be no schedule used. Examples included very small projects, time and materials (T & M) work, and projects built during the winter or in extreme weather conditions.

Input was provided on the use of client-supplied labor or client-specified subcontractors on agricultural projects. Some respondents discourage both of these practices, while other respondents would allow these practices as long as they were able to control the labor or subcontractors. Figure 9 shows the comparative likelihood of specific factors causing delays in agricultural construction. High percentages of respondents indicated a likelihood for the following factors: weather (55% very likely, 39% likely); labor (18% very likely, 36% likely); subcontractor delays (18% very likely, 52% likely); and approval of permits, inspections, and plans (46% very likely, 21% likely). Low percentages of respondents indicated a likelihood for the following factors: equipment (9% very likely, 21% likely); material (16% very likely, 23% likely); and interaction (5% very likely, 30% likely). Examples of other factors that could cause delays included zoning, financing, public utilities, and the customer making changes during the project.



The responses to the relative number of projects that were completed ahead of schedule, on schedule, or behind schedule for agricultural buildings are summarized in Table 11. The numerical value represents the number of projects out of 5 for each category. The average is 1.8 for ahead of schedule, 2.4 for on schedule, and 0.8 for behind schedule. Figure 10 compares the average on-time performance for all categories of construction to agricultural construction. Notice that compared to the overall on-time performance values, the average for completion ahead of schedule is higher and the average for completion behind schedule is lower for agricultural projects.

Table 11. On-time performance for agricultural projects

Performance level (out of every 5 projects)	Average	Share of total (%)
Projects completed ahead of schedule	1.8	35.3
Projects completed on schedule	2.4	47.9
Projects completed behind schedule	0.8	16.8
Total	5.0	100.0

Figure 10. On-time performance of survey respondents

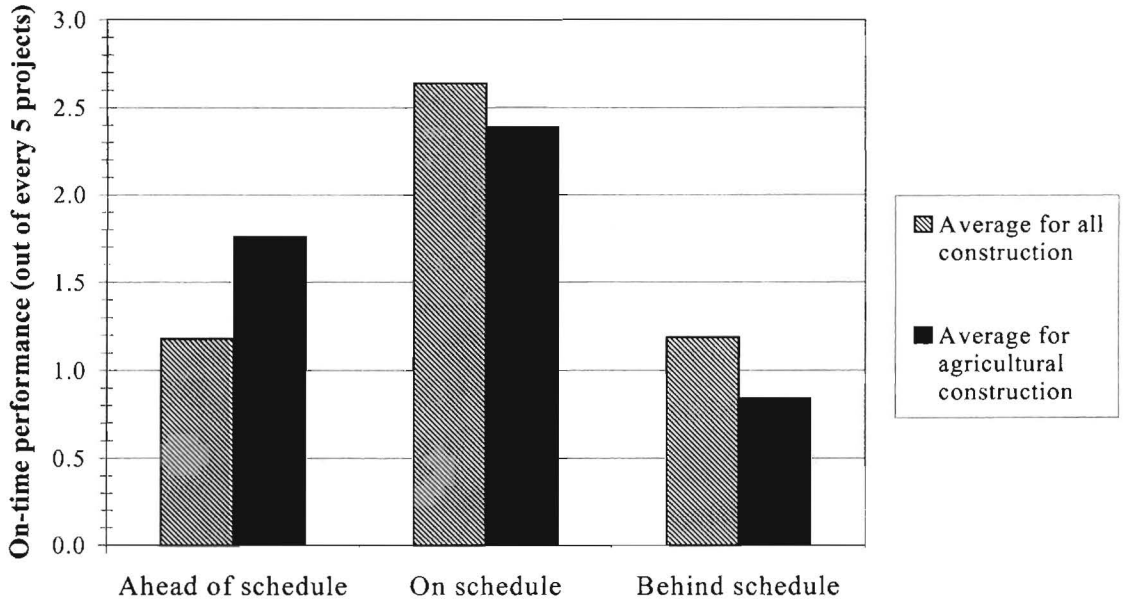


Figure 11 shows the likelihood of respondents using a scheduling tool for a machine shop project. The percentage of respondents who would very likely or likely use a scheduling tool for such a project is 61%.

Figure 11. Likelihood of using a scheduling tool for a machine shop

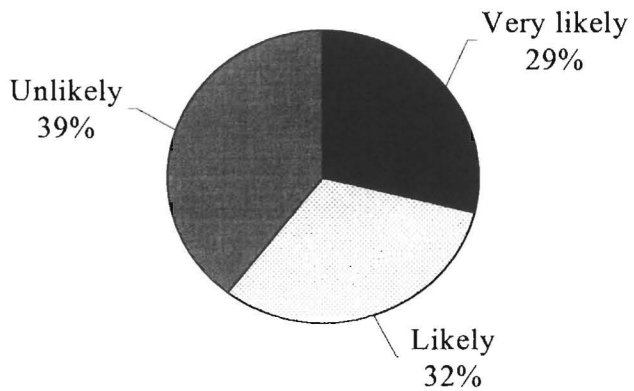
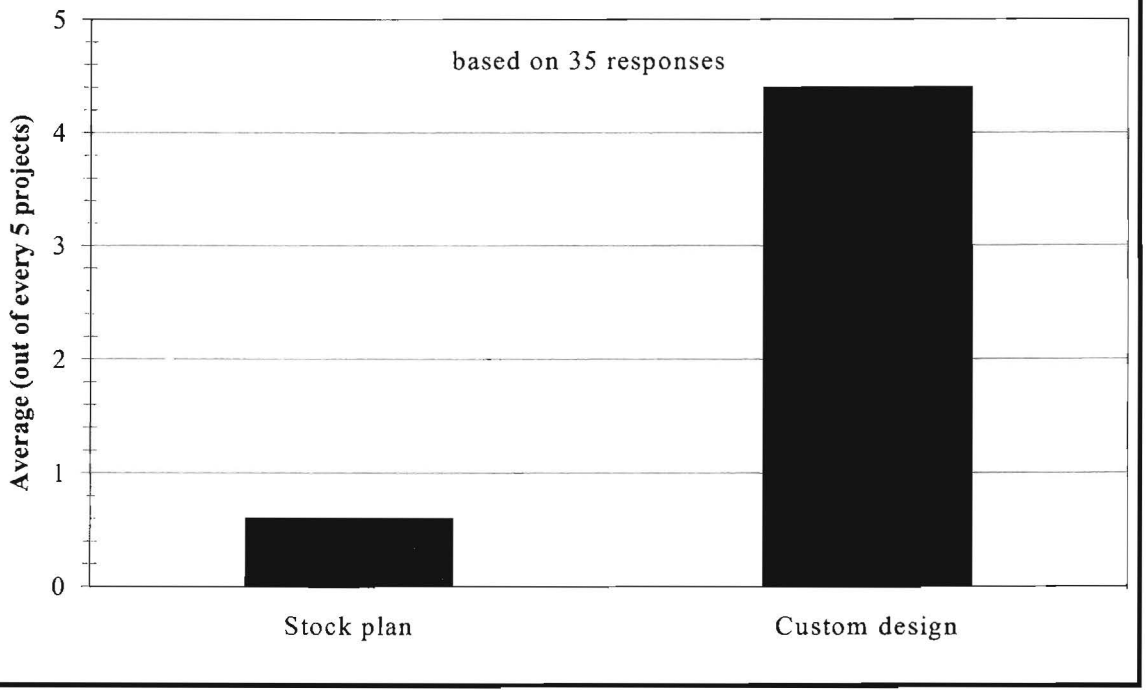


Figure 12 shows the types of plans that are generally used for machine shops, indicated by number of projects out of five. Custom-designed plans were used on the highest number of projects, 4.4 out of 5.0 (88%).

Figure 12. Types of plan used for a machine shop



Respondents described the effects of certain building features on the scheduling process for a machine shop. Some of the comments are as follows:

Lifts, hoists, pits: concrete detailing, excavation, long lead time for equipment.

HVAC: time for subcontractors to do their work.

Office area: layout for traffic flow, scheduling after HVAC, electrical, and plumbing work.

Special storage systems: conveyors.

Special utility needs: extra sitework, waiting on electric company, slow electrical suppliers.

Figure 13 shows the likelihood of respondents using a scheduling tool for a livestock building project. The percentage of respondents who were unlikely to use a scheduling tool for such a project is 52%.

Figure 13. Use of a scheduling tool for a livestock building

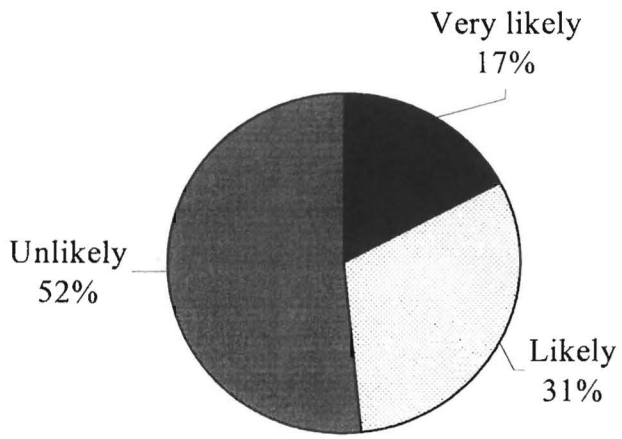
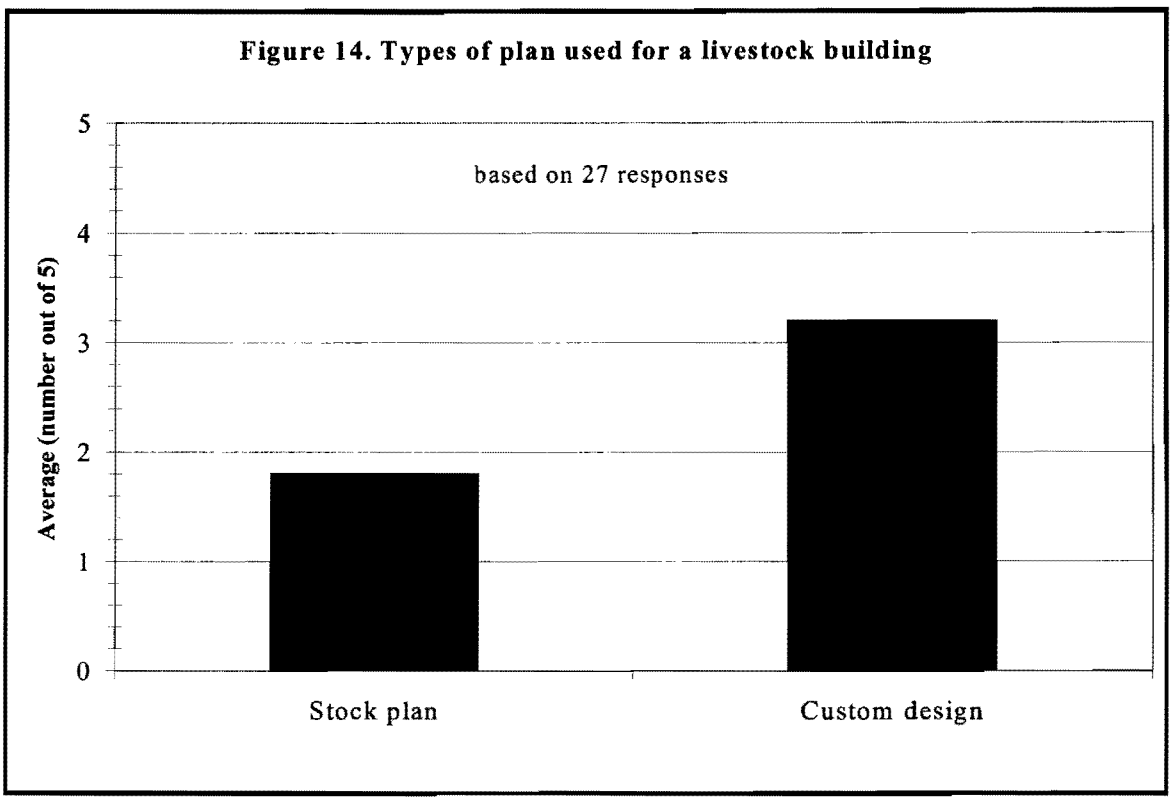


Figure 14 shows the types of plans that are generally used for livestock buildings, indicated by number of projects out of five. Custom designed plans were used on the highest number of projects, 3.2 out of 5.0 (64%).



Respondents described the effects of certain building features on the scheduling process for a machine shop. Some of the comments are as follows:

HVAC: longer lead time, long design time.

Special feeding systems: long lead time, more labor.

Treatment areas: design time, approvals.

Manure handling systems: design time, approvals.

As described previously, the on-time performance for agricultural building projects was slightly better than that of all categories of construction. There are some possible reasons for this. First, some types of agricultural buildings are based on standard or stock plans. For these types of buildings, contractors will be able to more easily predict project duration after completing several such buildings. Second, agricultural building designs do not usually have to be approved by a registered engineer, unlike most other categories of construction. This eliminates what is sometimes a time-consuming step in the construction process. In general, construction of such buildings seemed to follow a more streamlined process, as compared to other types of construction.

Respondents also reported steps they have taken to improve scheduling at their companies. The following are selected examples:

Hiring better-educated, and more responsible employees.

Providing employee bonuses.

Being more detail-oriented.

Developing an in-house coordinator.

Training employees.

Contacting subcontractors and suppliers more regularly.

Pressuring subcontractors and suppliers.

Identifying long lead items.

Developing an estimating database with man-hours required for activities.

Using better labor and subcontractors, no client labor or subcontractors.

Hiring additional labor.

Not scheduling work too far in advance.

Using a scheduling board showing crews and dates.

The development of an in-house coordinator is a concept that seems to have potential for improving scheduling. If an individual solely has the responsibility to schedule and coordinate projects, it seems likely that scheduling will be improved. This is compared to an individual who is responsible for sales, estimating, and scheduling at the same time, for example.

Another step that would seem to have potential is development of an estimating database, in conjunction with the use of an estimating software package. With an estimating database, not only is the estimating process more efficient, but so is the scheduling process. This is especially true if the database contains man-hours for activities. Software packages are available that integrate estimating, scheduling, cost control, and other features. For some companies, such a package might be worth the investment for improving the scheduling process, and potentially on-time performance.

VII. Conclusions

This study evaluated construction-scheduling practices from the perspective of the contractor. Information was collected through a survey and was analyzed using three statistical analyses to determine those specific schedule-related factors that affect on-time performance. We made three conclusions about factors of on-time performance.

(1) Two factors definitely affect on-time performance: the scheduler has experience as a superintendent, and the contractor provides a finish date in advance.

(2) Two additional factors probably affect on-time performance: the scheduler uses past projects as resources, and the contractor provides milestone dates in advance.

(3) a.) Eight other factors may positively affect on-time performance: an individual person is responsible for scheduling, the scheduler has formal training, the scheduler has a college education, the contractor provides a start date in advance, the scheduler includes float time to allow for delays, the scheduler uses computer programs as resources, the scheduler uses books and manuals as resources, and the scheduler has experience as a project manager.

b.) Four factors may negatively impact on-time performance: the scheduler uses other resources for scheduling, the company constructs premanufactured buildings, a scheduling department is responsible for scheduling, and the scheduler uses conservative time estimates to allow for delays.

The results of this study show that there are factors under management's control that can improve on-time performance. A very important part of a successful construction business is completing building projects on schedule. For this reason, contractors should consider these factors when determining desired qualifications of schedulers and selecting practices to employ in developing construction schedules.

The following areas merit further investigation: (1) the connection between the use of formal scheduling, on-time performance, and profitability, (2) the reasons that some contractors do not use formal scheduling, (3) the higher on-time performance for agricultural construction projects, and (4) on-time performance of companies before and after steps are taken to improve on-time performance. The importance of formal scheduling is not significant unless it improves the contractor's bottom line. Efforts to assist contractors in the

implementation of formal scheduling practices can be facilitated by an understanding of why they are resistant to them.

Appendix A – Scheduling Survey

General Information

1. How many employees does your company have?_____
2. How many crews does your company normally have?_____
3. Please give an approximate amount of annual sales._____
4. Please give an approximate number of projects completed annually, based on the past two years._____
5. By percentage, what types of construction do you perform?

   ___Agricultural ___Residential ___Commercial ___Industrial

   ___Other - Please list:_____
6. Do you construct pre-manufactured buildings? Yes____ No____

   If so, for what manufacturer?_____

General Scheduling Information

Please submit a sample or generic schedule that reflects what your company uses most frequently.

7. Who does the scheduling in your company?

   ____Department name :_____

   ____Individual(s) title:_____
8. How were your schedulers trained?

   ___Formal classes (Circle most common: College Technical school Company classes)

   ___Informal training

   ___On-the-job training
9. What is the highest level of construction experience of the scheduler(s)?

   (Check all that apply).

   ___Laborer ___Superintendent ___Project manager ___Estimator ___None

   ___Other - Please describe:_____
10. Which of the following resources do you use to assist in scheduling?

    ___Books/manuals ___Computer programs ___Past projects

    ___Other - Please list:_____

11. Based on the past two years, how many out of every five projects have been completed:

Ahead of schedule	(	0	1	2	3	4	5)
On schedule (within one week)	(	0	1	2	3	4	5)
Behind schedule	(	0	1	2	3	4	5)

12. Which of the following best describes how your most frequently used scheduling method allows for delays?

___Conservative time estimates for project activities.

___Float time included for non-critical tasks.

___Other - Please describe:

13. What are the main consequences of scheduling errors to your company?_____

_____

_____

14. For most of your company's projects, what information is usually given to customers?

Circle all that apply: Start date Finish date Itinerary Milestone dates

15. Out of every five projects, how many would include schedule-related incentives or penalties written into the contract? (0 1 2 3 4 5)

16. Briefly describe your most commonly used incentives or penalties._____

_____

_____

Scheduling for Agricultural Construction

The following questions apply specifically to the construction of agricultural buildings.

17. List or describe any resources your company uses that provide scheduling information specific to agricultural construction._____

_____

_____

18. Do you use the same scheduling routine on all projects? Yes_____ No_____

If not, what determines the scheduling method used? _____

_____

_____

19. Identify occasions when you would not do any scheduling._____

_____

_____

20. What is your policy for using client-supplied labor or client-specified subcontractors during construction?_____

_____

_____

21. For each of the following events or circumstances, rate the likelihood that it will delay a project once construction is started?

Inclement weather	__Very likely	__Likely	__Unlikely
Equipment problems	__Very likely	__Likely	__Unlikely
Labor availability	__Very likely	__Likely	__Unlikely
Material availability	__Very likely	__Likely	__Unlikely
Interaction (or lack of) with customer	__Very likely	__Likely	__Unlikely
Subcontractor delays	__Very likely	__Likely	__Unlikely
Approval of permits, inspections, plans	__Very likely	__Likely	__Unlikely

Please describe any other common reasons for delays not listed above._____

_____

22. Based on the past two years, how many out of every five agricultural construction projects have been completed:

Ahead of schedule	(	0	1	2	3	4	5)
On schedule (within one week)	(	0	1	2	3	4	5)
Behind schedule	(	0	1	2	3	4	5)

23. Please describe any steps that you are currently taking to improve scheduling accuracy._____

_____

_____

_____

Scheduling for a Machine Shop

24. How likely are you to use a scheduling tool in constructing a typical machine shop?

___Very likely ___Somewhat likely ___Not likely

25. Which scheduling tool would be used most often for a typical machine shop?

_____

_____

_____

26. For the following, indicate if and how the feature typically affects scheduling for a machine shop.

Lifts, hoist, pits, etc._____

HVAC_____

Office area_____

Special storage systems_____

Special utility needs_____

Other_____

27. Out of every five typical machine shops that you construct, how many have building designs that are:

Based directly on stock plans (0 1 2 3 4 5)

Custom designed (0 1 2 3 4 5)

Scheduling for a Livestock Housing Building

28. How likely are you to use a scheduling tool in constructing a typical livestock barn?

___Very likely ___Somewhat likely ___Not likely

29. What scheduling tool would be used most often for a typical livestock building?____

_____

30. For the following, indicate if and how the feature typically affects scheduling for a livestock building.

HVAC_____

Special feeding systems_____

Treatment areas_____

Manure handling systems_____

31. Out of every five typical livestock buildings that you construct, how many have building designs that are:

Based directly on stock plans (0 1 2 3 4 5)

Custom designed (0 1 2 3 4 5)

Appendix B – Scheduling Survey Results

*Note that some "total percentages" add to more than 100% when more than one response could be indicated (i.e. choice questions).

Table B1. General contractor information

Variable	Minimum	Maximum	Average	Standard deviation
Employees	1	560	28	80
Crews	0	12	3	2
Sales	$200,000	$120,000,000	$5,600,000	$18,000,000
Sales per employee	$29,000	$875,000	$206,000	$161,000
Sales per crew	$188,000	$6,700,000	$913,000	$1,100,000
Projects	4	225	47	44
Projects per employee	0.1	50.5	5.7	8.3
Projects per crew	1.7	75.0	17.1	14.0

Table B2. Type of construction

Type of construction	Average percentage
Agricultural	30.7
Residential	19.0
Commercial/industrial	47.0
Other	2.4
Total	99.1

Table B3. Use of premanufactured buildings

	Number using	Number not using
Premanufactured buildings	27	20

Table B4. Scheduling entity

	Number	Share of total (%)
Scheduling by department	11	24.4
Scheduling by individual	40	88.9
Total	51	113.3

Table B5. Level of scheduler training

	Number	Share of total (%)
College	5	10.6
Tech school	2	4.3
Company class	1	2.1
Informal	7	14.9
On-the-job	43	91.5
Total	58	123.4

Table B6. Construction experience of scheduler(s)

	Number	Share of total (%)
Laborer	17	37.0
Superintendent	19	41.3
Project manager	35	76.1
Estimator	31	67.4
None	1	2.2
Other	11	23.9
Total	114	247.9

Table B7. Resources used to assist in scheduling

	Number	Share of total (%)
Books	15	31.9
Computer programs	17	36.2
Past projects	39	83.0
Other	5	10.6
Total	76	161.7

Table B8. On-time performance

Performance level (out of every 5 projects)	Average	Share of total (%)
Projects completed ahead of schedule	1.2	23.5
Projects completed on schedule	2.6	52.7
Projects completed behind schedule	1.2	23.8
Total	5.0	100.0

Table B9. Scheduling method used to allow for delays

	Number	Share of total (%)
Conservative time estimates	28	65.1
Float time included	9	20.9
Other	6	14.0
Total	43	100.0

Table B10. Schedule-related dates provided in advance

	Average	Share of total (%)
Start date	40	83.3
Finish date	22	45.8
Itinerary	10	20.8
Milestone dates	13	27.1
Total	85	177.0

Table B11. Projects with schedule-related incentives or penalties

	Average	Share of total (%)
Incentives or penalties included (out of every 5 projects)	0.5	9.2

Table B12. Use of same scheduling method for all agricultural projects

	Number	Share of total (%)
Same scheduling method	27	75.0
Different scheduling method	9	25.0
Total	36	100.0

Table B13. Likelihood of factors causing delays

Factor	Percent of respondents indicating		
	Very likely	Likely	Unlikely
Weather	54.5	38.6	6.8
Equipment	9.1	20.5	70.5
Labor	18.2	36.4	45.5
Material	15.9	22.7	61.4
Interaction with customer	4.5	29.5	65.9
Subcontractor delays	18.2	52.3	29.5
Approval of permits, inspections, plans	45.5	20.5	34.1

Table B14. On-time performance for agricultural projects

Performance level (out of every 5 projects)	Average	Share of total (%)
Projects completed ahead of schedule	1.8	35.3
Projects completed on schedule	2.4	47.9
Projects completed behind schedule	0.8	16.8
Total	5.0	100.0

Table B15. Likelihood of using a scheduling tool for a machine shop

	Number	Share of total (%)
Very likely	11	28.9
Likely	12	31.6
Unlikely	15	39.5
Total	38	100.0

Table B16. Types of plan used for a machine shop

Type of plan (out of every 5 projects)	Average	Share of total (%)
Stock plan used	0.6	12.0
Custom design developed	4.4	88.0

Table B17. Likelihood of using a scheduling tool for a livestock building

	Number	Share of total (%)
Very likely	5	17.2
Likely	9	31.0
Unlikely	15	51.7
Total	29	99.9

Table B18. Types of plan used for a livestock building

Type of plan (out of every 5 projects)	Average	Share of total (%)
Stock plan used	1.8	35.2
Custom design developed	3.2	64.1

Appendix C – Effects of Other Variables in Regression Analysis

Several variables were eliminated in the regression analysis, due to high p-values. While they were not statistically significant, the lists below note how they affected on-time performance based on the value of the parameter estimate.

Positive effect	Negative effect
Department	Premanuf.
College	Tech school
Company class	Books
Computer	Other res.
Float	Conservative
Other delay*	Penalty
Itinerary	Informal
Milestone date	On-the-job
Formal training	Laborer
Project mgr.	Estimator
	None
	Other exp.

*parameter estimate = 0

Appendix D – Odds Ratios Illustration

Consider the effects of a fictitious construction practice called "widgeting" on the construction of 74 projects. The breakdown of on-time performance for these projects is tabulated below.

		Project completed on time		
Use widgeting		No	Yes	Total
	No	30	20	50
	Yes	8	16	24
	Total	38	36	74

In this illustration, the odds of completing a project on time increased three-fold for those projects where widgeting was used compared to where it was not (20/30 = 2/3 vs. 16/8 = 2), so the odds ratio is 3. In other words, if the odds of a company completing a project on time were 1:1 without widgeting, the odds should be 3:1 with widgeting.

The odds ratios that are obtained from logit analysis are multiplicitive. Suppose in addition to widgeting, there is another practice called "gadgeting", and the odds ratio of gadgeting is 2. The odds of completing a project on time with widgeting alone are 3:1. If gadgeting is also used, the odds would improve to 6:1 (3 x 2 = 6).

Section 2: Customer Perspective

Abstract

The authors evaluated issues related to construction scheduling from the perspective of customers of agricultural buildings. Information about customers' experiences during recently completed building projects was collected via mail surveys. To determine which factors affected customer satisfaction with construction progress, we conducted three statistical analyses: regression, simple odds ratio, and logit. Based on the results of these analyses, we concluded that two factors probably affect customer satisfaction: the building design is copied from another facility, and construction is finished on time. Five factors may affect customer satisfaction: the customer supplies labor, the customer specifies one or more subcontractors, the building design is based on a builder's stock plan, construction starts on time, and schedule delays result in added costs.

I. Introduction

A common perception is that scheduling impacts customer satisfaction with construction projects. In a society where timeliness is prioritized and availability of products on demand is valued, a logical expectation is that customer satisfaction would be tied to completion of building projects on schedule. In this report, the second in a two-part study, we evaluated the effects of several scheduling variables on customers' satisfaction with construction progress.

II. Data Collection

A customer survey was developed to collect information about customers' experiences during recently completed building projects. The survey was mailed to 55 individuals in Ohio who had an agricultural building (machine shop/storage or livestock facility) constructed within the past two years. Those who received surveys were identified with the assistance of county extension agents. Thirty-three surveys were returned. Of these, 27 were complete and valid for the study. Surveys were considered invalid if the customer

was the general contractor or if the building was considered to be more of an addition than a new structure.

III. Data Description

The customer survey collected data about (1) general customer information and (2) scheduling information based on the building that was recently constructed. Appendix A provides the survey questions and Appendix B contains a numerical summary of the survey results.

A. General Information

The first section of the customer survey provided general information about the building project. First, the customers described the size, primary usage, and unique features of the building. They also gave the name of the general contractor. Second, they indicated whether the building was premanufactured. Third, the customers reported whether they supplied any labor, or specified or hired any subcontractors for the project. Finally, the customers identified how plans were developed.

B. Scheduling Information

The second section of the customer survey provided schedule-related information about the project. First, the customers reported whether they had desired start and finish dates in mind and whether any such dates were proposed by the builder. For each of these, customers identified the dates where applicable. Second, the customers described schedule-related penalties or incentives that were written into the contract. Third, they reported the actual start and finish dates. All requested dates were provided to the nearest week. By comparing the actual start and finish dates, we determined whether projects were started and finished on time, according to the customer's recollections and viewpoint. Fourth, the customers described the causes of any delays that may have occurred. Fifth, they indicated whether the delays, if any, added to the cost of the respective building projects. Sixth, they identified their level of satisfaction with construction progress. Finally, they suggested any steps they could have taken to improve the timeliness of the project.

IV. Methodology and Analysis

The effects of various factors on customer satisfaction with construction progress were analyzed statistically. The data from the survey were tabulated in a spreadsheet using the same methodology as for the contractor survey. The statistical package SAS was again used to perform three types of statistical analyses: (1) multiple regression analysis, (2) simple odds ratios, and (3) logit analysis. In each analysis the dependent variable was "Satisfied". The value of this variable was either zero or one, and indicated whether or not the customer was satisfied with the progress of construction during the project.

V. Results and Discussion

A. Survey Results – General Information

The results of the first section of the scheduling survey provided basic information about the buildings that were recently constructed. Table 1 summarizes information related to the size of the buildings described by customers in the survey. Livestock buildings include freestall barns, milking parlors, hog finishing, and nursery building. Multiple-use buildings include those that have a combination of uses. Figure 1 shows the types of buildings described by customers in the survey. The highest percentage of respondents (67%) had livestock buildings constructed recently, while the lowest percent (11%) had multiple-use buildings constructed recently. Figure 2 shows that only 11% of the respondents used premanufactured buildings.

Table 1. Building sizes of 24 customers who responded to the survey (in square feet)

	All buildings	Equipment storage	Livestock	Multiple-use
Average	8,270	3,200	15,360	18,480
Maximum	47,000	4,860	44,780	47,000
Minimum	600	600	1,150	3,840

Figure 1. Uses of recently constructed buildings

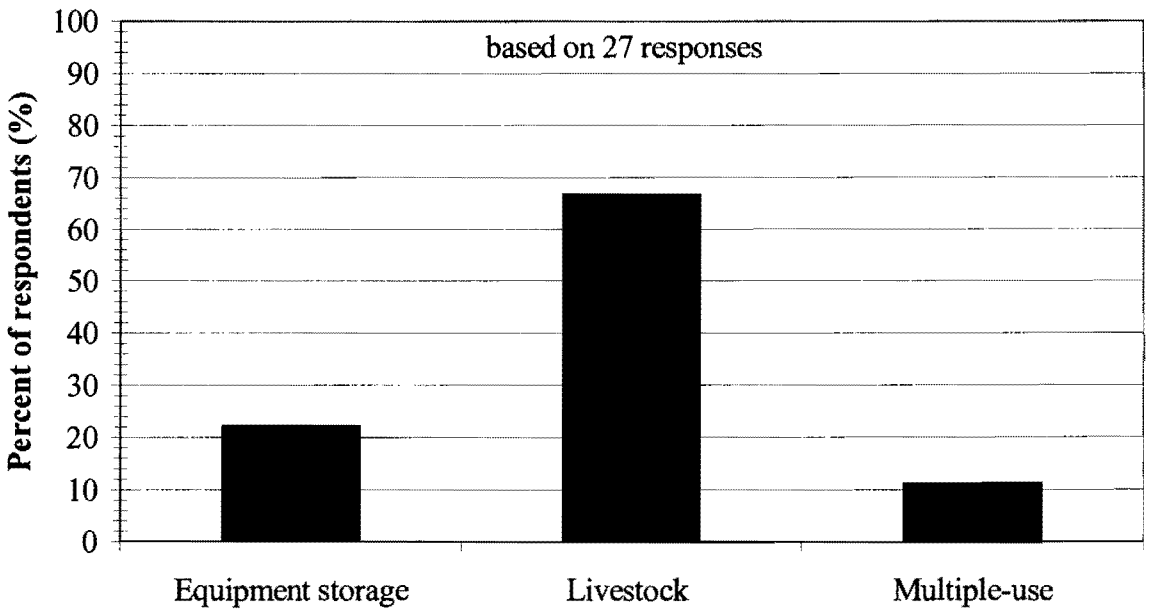


Figure 2. Use of premanufactured buildings
based on 27 responses

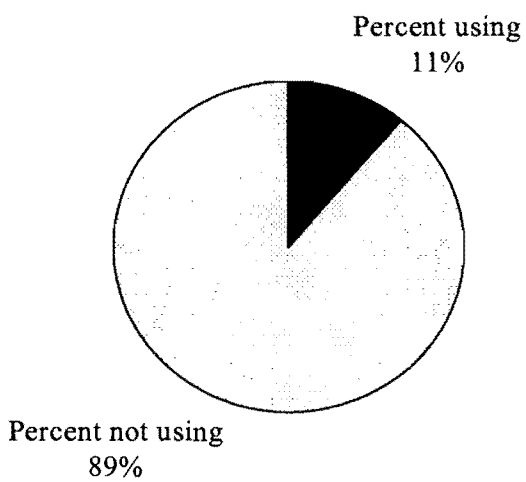
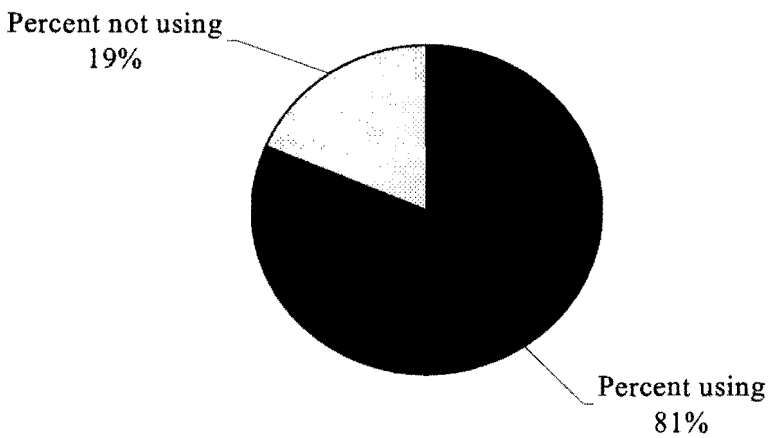


Figure 3 shows that 81% of respondents either supplied their own labor or agreed to perform some of the work necessary to complete the project. Figure 4 shows the tasks completed by those respondents who supplied labor or performed some of the work. Sitework/excavation and concrete were the tasks reported by the highest percentage of respondents (23%), while framing was reported by the lowest percentage of respondents (8%).

Figure 3. Use of customer-supplied labor
based on 27 responses



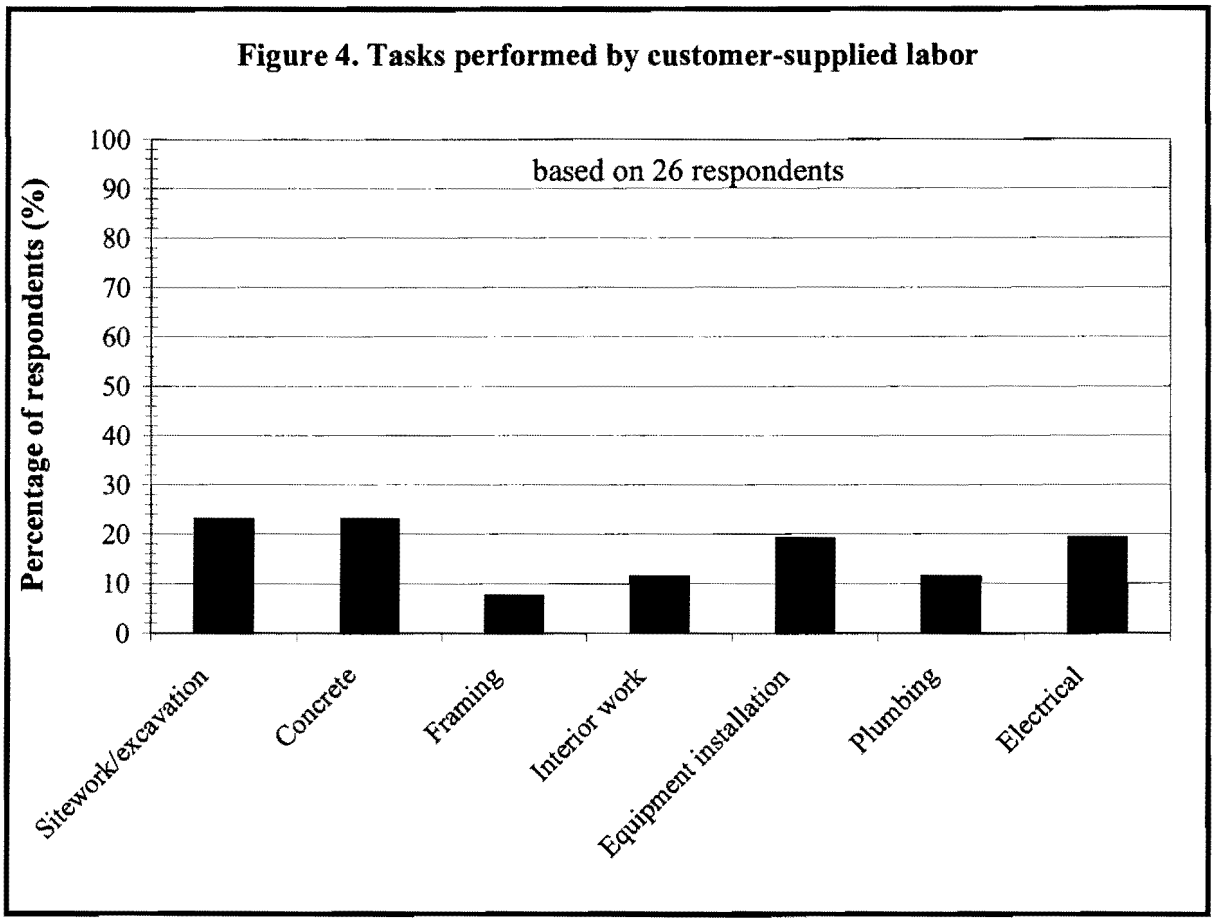


Figure 5 shows that 52% of respondents specified or hired subcontractors to perform some of the work necessary to complete the project. Figure 6 shows the tasks completed by subcontractors that were hired or specified by the customer. Sitework/excavation was performed by these subcontractors for the highest percentage of respondents (47%), while roofing/siding and HVAC were performed by these subcontractors for the lowest percentage of respondents (6%).

Figure 5. Use of customer-specified or -hired subcontractors
based on 27 responses

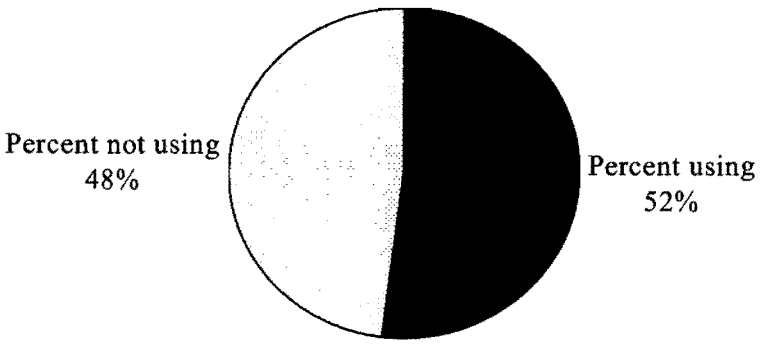


Figure 6. Tasks performed by customer-specified or -hired subcontractors

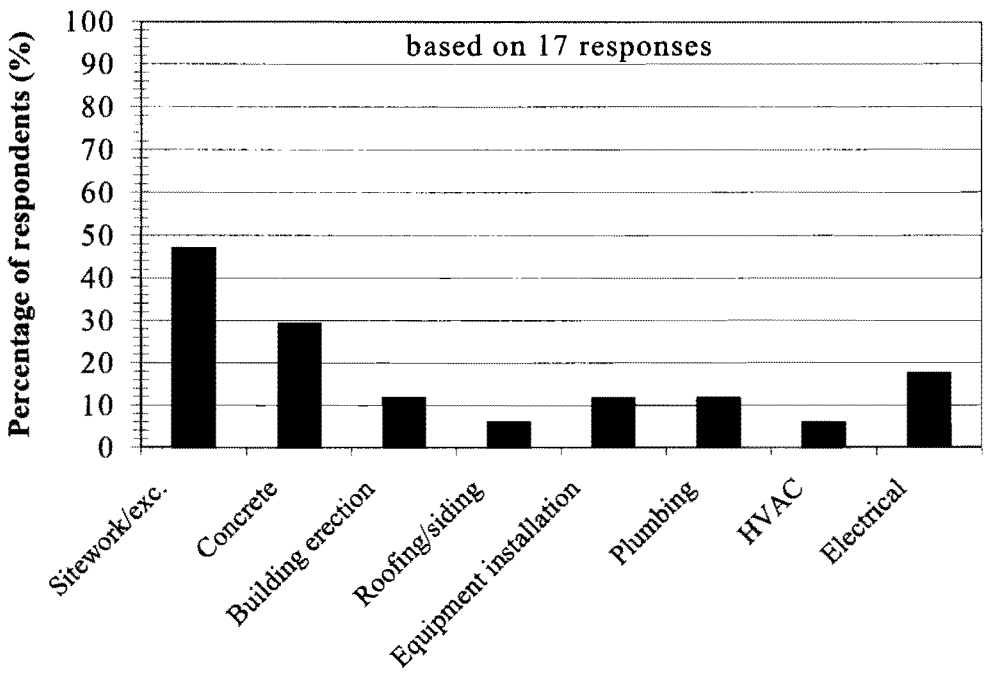
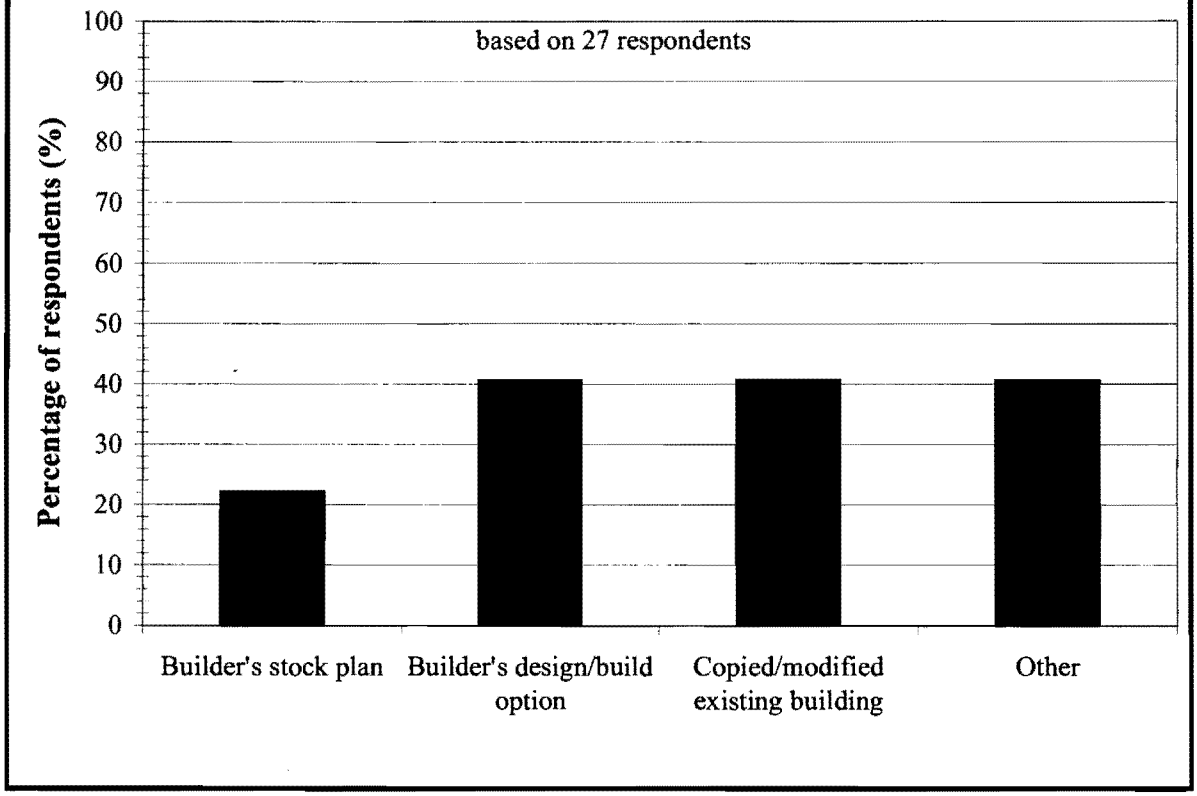


Figure 7 shows which methods were used for designing the building plans. The highest percentage of respondents (41%) used the builder's design/build option, copied or modified an existing building, or used sources other than the builder for plan development. Builder's stock plans were used by the lowest percentage (23%) of respondents. Sources other than the builder that were reported to included self-designed, Hoards Dairyman, and the Midwest Plan Service.

Figure 7. Method used to design building plans

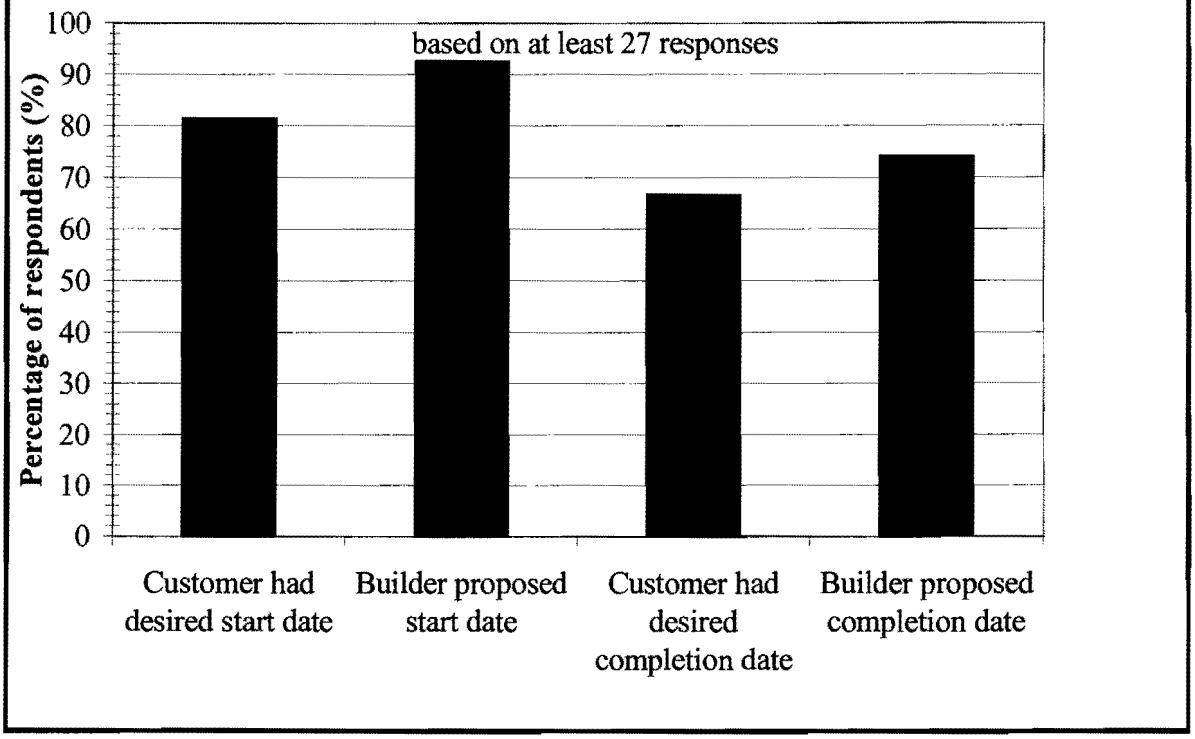


B. Survey Results – Scheduling Information

The second section of the survey provided information related to scheduling and actual construction progress. Figure 8 shows the schedule-related dates that were desired by

the customer and proposed by the builder. A higher percentage of respondents (82%) had a desired start date than a completion date (67%). A higher percentage of respondents (93%) reported that the contractor proposed a start date than a completion date (74%).

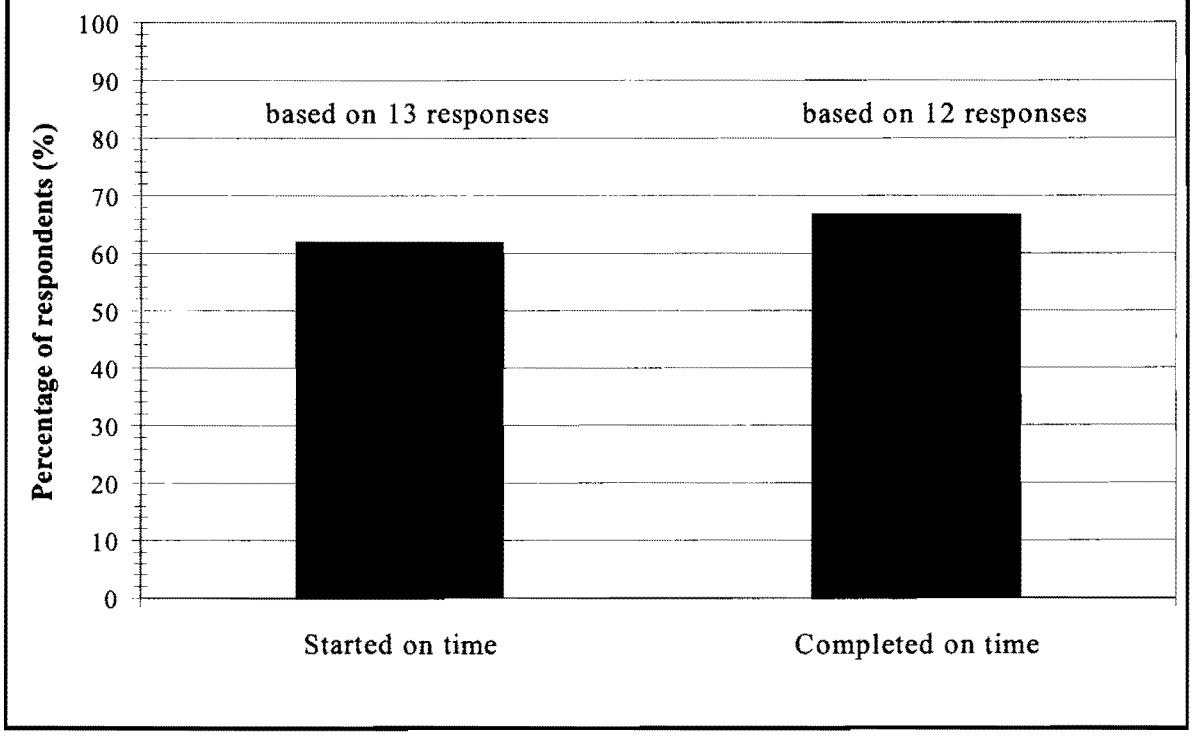
Figure 8. Provision of schedule-related dates



Respondents were asked to describe schedule-related incentives or penalties that were written into the contract. The only response supplied for this question was that the customer would provide more work if the builder's performance was satisfactory.

Figure 9 shows the on-time performance reported by customers for their building projects. 62% of respondents reported the project started on time, and 67% of respondents reported the project was completed on time.

Figure 9. On-time performance on projects



Respondents described the causes of delays that occurred during their building projects. Figure 10 shows the percentages of respondents who reported having delays in each major category. Examples of weather delays included rain, wind, and snow. Examples of labor delays were the builder was busy, and crews arrived late. Examples of equipment delays were a subcontractor ordered equipment and lost it, and some items were of poor quality. Examples of material delays were equipment arrived late and damaged, and the wrong equipment was received. Examples of unspecified builder and subcontractor delays were concrete work was unfinished, the builder was called away on other jobs, inexperience with the size of the building, and the builder underestimated the time to complete tasks.

Figure 10. Number of respondents who reported specific causes of delays

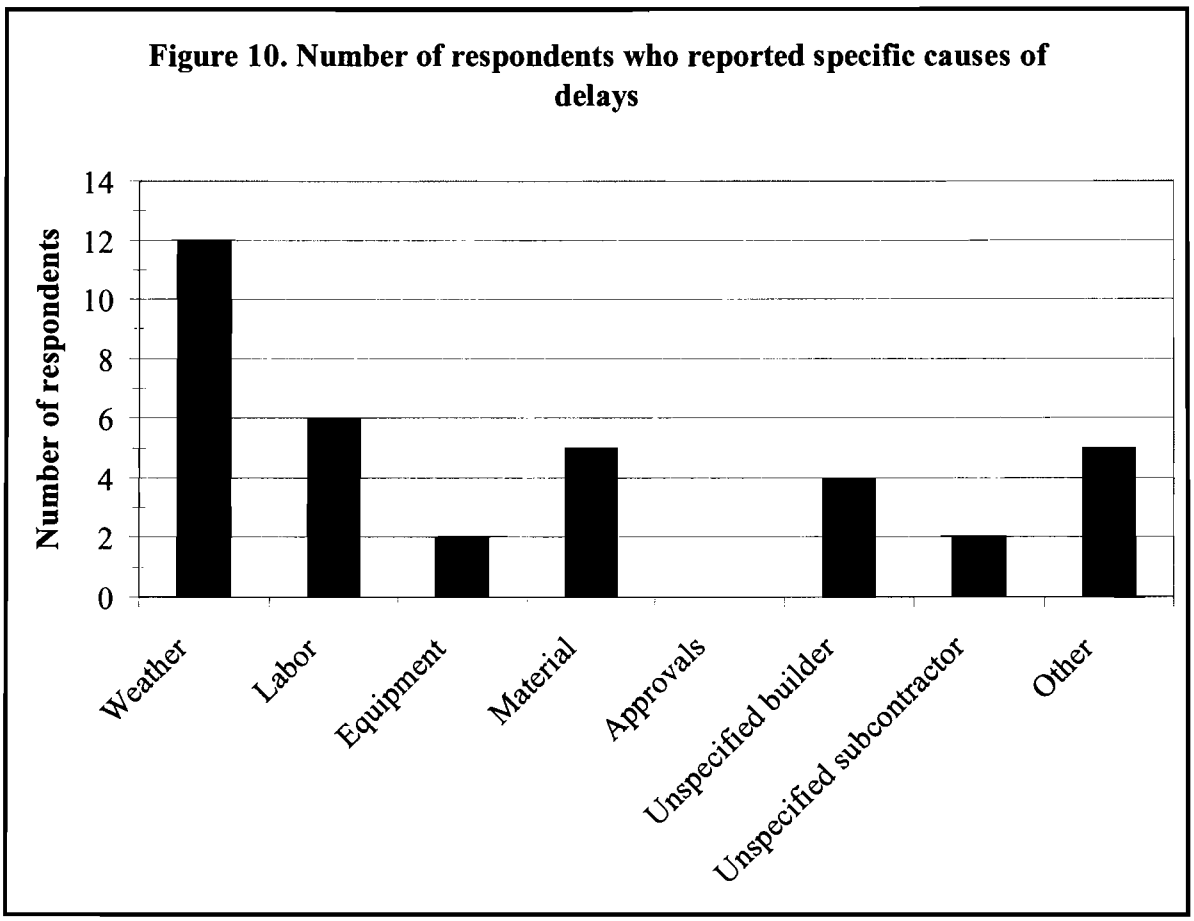


Figure 11 shows that 70% of respondents did not have additional costs because of delays in project completion, or at least did not associate any costs with delays. Respondents described how these additional costs occurred. Some responses included: old livestock facility was overcrowded resulting in lost income from possible production increases in new facility; unable to move into a new livestock facility before hot weather, resulting in lost income; and delays caused higher farm labor costs.

Figure 11. Association of project delays with added costs
based on 20 responses

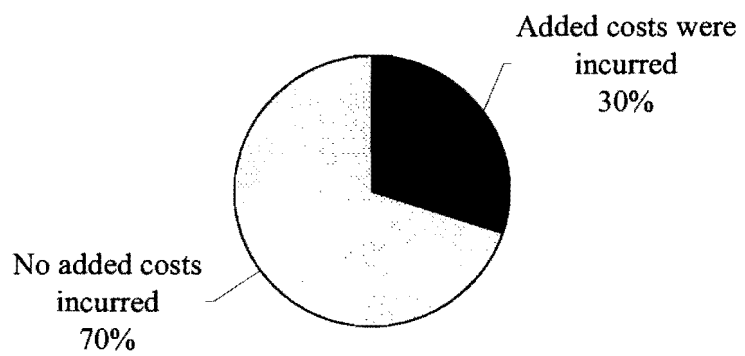
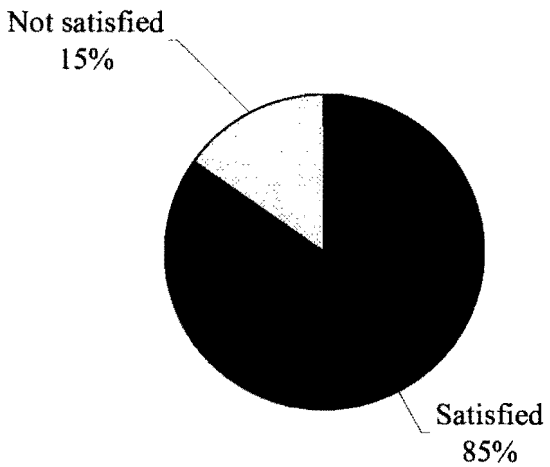


Figure 12 shows that 85% of respondents were satisfied with progress made during building construction. Respondents explained their reasoning for satisfaction or dissatisfaction. Reasons for satisfaction included: the builder worked hard, the builder was efficient, preplanning resulted in elimination of foreseen problems, and the workers knew their responsibilities. Reasons for dissatisfaction included: the builder started too late, the builder was working on too many projects, and the supplier caused delays.

Figure 12. Customer satisfaction with progress of building construction
based on 26 responses



Respondents also described what steps they could have taken to improve the timeliness of their building projects. Some of the responses are as follows: do more planning, include a time completion clause in the contract with a penalty for not completing the project on time, watch the quality of work more closely, build under better weather conditions, and have the equipment dealer install equipment instead of builder.

C. Statistical Analysis

Table 2 provides an explanation of each of the variables used in the statistical analysis. Variable names include the number of the corresponding survey question. Table 3 shows the variables that positively influenced customer satisfaction with significance at the 15% confidence level. This level was selected because it provided a reasonable level of statistical confidence for the nature of the data, and because it was readily applied across the three analyses.

Table 2. Explanation of variables used in analyzing data from the customer survey

Variable name	Explanation	Response type	Survey question number
	Dependent variable		
Satisfied		Yes/no	15
	Independent variables		
Premanuf.	Premanufactured building was used	Yes/no	2
Labor	Customer supplied labor	Yes/no	3
Subcontractor	Customer specified one or more subcontractors	Yes/no	4
Stock plan	Building design was based on a builder's stock plan	Choice	5
Design build	Building design was produced utilizing custom design/build option	Choice	5
Copied design	Building design was copied from another one	Choice	5
Other source	Building design was based on information from a source other than the builder	Choice	5
Desired start	Customer had a desired start date ahead of time	Yes/no	6
Actual start	Builder proposed a start date	Yes/no	7
Desired completion	Customer had a desired completion date ahead of time	Yes/no	8
Actual completion	Builder proposed a completion date	Yes/no	9
On-time start	Construction started on time	Derived	7,11
On-time finish	Construction finished on time	Derived	9,12
Added cost	Schedule delays resulted in additional costs	Yes/no	14

Table 3. Factors that affected customer satisfaction (significant variables by statistical analysis); (+denotes positive effect, - denotes negative effect)

Variable	Regression analysis	Simple odds ratios	Logit analysis
Copied design	+	+	
On-time finish	+	+	
Added cost	+		
Stock plan		+	
On-time start		+	
Labor		+	
Subcontractor		+	
Design build		-	

1. Regression analysis

The results of the regression analysis (Table 4) showed that three factors positively affected customer satisfaction: On-time finish, Copied design, and Added cost. Each of these variables had a p-value lower than 0.10, with On-time finish having the lowest, 0.01. The effects of variables that were not significant are summarized in Appendix C.

Table 4. Regression analysis results for statistically significant ($p \leq 0.15$) factors of customer satisfaction

Variable	Parameter estimate	p-value
On-time finish	0.527	0.005
Copied design	0.344	0.032
Added cost	0.336	0.076

The magnitude of the effect of each variable can be determined using the parameter estimate. The parameter estimate indicates the percentage improvement in the likelihood of customer satisfaction that will occur. For example the parameter estimate for On-time finish is 0.53. This means that if the project was completed on time, there is a 53% higher likelihood of customer satisfaction with construction progress than if the project was completed behind schedule.

The first factor that affected customer satisfaction with construction progress was on-time completion of construction. If a building is finished on time, the customer can use it as he or she planned at the expected time. Often a customer may plan for the building to be completed by a certain date for specific pre-contracted, business-related needs, such as livestock delivery dates. Even if there are no specific business-related needs, customers usually have an innate desire for timeliness.

The second factor was whether the design of the building was copied or modified from another facility. A customer would likely base a building design on plans for an existing building because he or she liked certain features of that building. The advance inclusion of such features in the new facility logically may affect his/her overall satisfaction with the building project. There may also be some efficiencies gained during construction if the customer and/or builder were quite familiar with how the copied facility was constructed.

The final significant factor was schedule delays resulting in added costs. This result was somewhat unexpected. This may reflect a general expectation that some cost overruns are likely. As long as reasonable progress occurred and attempts were made to overcome delays, additional costs probably did not lead to dissatisfaction. Also, added costs may have resulted from customer requests to enhance or modify the building during construction, resulting in an increased and associated level of satisfaction.

2. Simple Odds Ratios

The results of the simple odds ratio analysis (Table 5) showed that six factors positively affected the odds of customer satisfaction by a noteworthy degree: Stock plan, Copied design, On-time start, On-time finish, Labor, and Subcontractor. Each of these variables had a simple odds ratio higher than 2.0, with Stock plan, Copied design, On-time start, and On-time finish having the highest ratios. The results also showed that one variable had a negative effect on the odds of customer satisfaction: Design build. This variable had an odds ratio less than 0.50.

The numerical value of each odds ratio provides an indication of the improvement in the odds of customer satisfaction with construction progress through the implementation of that particular variable. For example, the odds ratio for labor is 3.2. This means that the odds of customer satisfaction with construction progress improved by a factor of 3.2 when the customer supplied labor. Therefore, if the odds of attaining customer satisfaction when the customer does not supply labor are 3:1, then the odds when the customer does supply labor should be approximately 9:1.

Table 5. Simple odds ratios for improving customer satisfaction with construction progress

Variable	Odds ratio
Stock plan	999*
Copied design	999*
On-time start	999*
On-time finish	999*
Labor	3.17
Subcontractor	2.40
Other source	1.67
Added cost	1.20
Design build	0.29
Desired start	0**
Desired completion	0**
Actual completion	0**
Premanuf.	***
Actual start	****

*A simple odds ratio of 999 indicates there were no affirmative responses for the independent variable that corresponded to the customer being not satisfied with building progress.

**A simple odds ratio of 0 in this case indicates there were no respondents who did not have this date who also were not satisfied with building progress.

***Insufficient affirmative responses for independent variable existed to perform a reasonable statistical analysis.

****Insufficient negative response for independent variable existed to perform a reasonable statistical analysis.

Two of these factors were described previously: building design was copied or modified from another, and construction was completed on time. The third and fourth factors were whether the customer supplied labor and the customer specified subcontractors, respectively. If a customer supplies labor then his or her standards of quality are more likely to be met, or at least dissatisfaction is less likely to be voiced. Similarly, if a customer specifies a subcontractor, the customer probably has some built-in acceptance of that subcontractor's performance. The specified subcontractor probably has a good reputation with the customer or knows the customer's expectations well.

The fifth factor was whether the design of the building was based on a contractor's stock plan. A contractor will probably construct a building based on a stock plan more efficiently, because of familiarity with the plan. This would more likely lead to fewer instances of misunderstanding between customer and builder, fewer surprises, and a higher

level of on-time completion. All of these factors likely contribute to high levels of customer satisfaction with construction progress.

The sixth factor was whether construction started on time. Even though an on-time start does not necessarily mean that construction will be finished on time, a late start probably makes it more difficult to complete the project on schedule, within budget, and with attention to detail. There is also probably a psychological effect on customers. If a project is started late the customer would likely already be dissatisfied to a certain extent. Also, if the project is started late but finished on time the customer may possibly suspect that the contractor did not do quality work, whether or not this is true.

One factor negatively affected customer satisfaction with construction progress. This factor was the customer utilized the builder's custom design/build option. Design/build projects may sometimes experience delays or revisions because the design work occurs hurriedly or while construction is in progress. Such delays could cause the customer to feel dissatisfied, especially if the perceived fault lies with the builder.

3. Logit Analysis

The logit analysis did not produce any statistically significant variables. Because this is the most discriminating analysis, it was expected to produce the least number of significant variables. The lack of significant variables in this analysis indicates that the variables that were identified as factors in the other analyses must be interpreted with caution.

VII. Conclusion

This study evaluated construction scheduling practices from the perspective of the customers of agricultural buildings. Information was collected through a survey and was analyzed using three statistical analyses to determine the specific factors that affected customer satisfaction with progress made during construction. We made two conclusions about factors that may improve customer satisfaction.

(1) Two factors probably affect customer satisfaction: the building design is copied from another facility, and construction is finished on time.

(2) a.) Five other factors may affect customer satisfaction: schedule delays result in added costs, the building design is based on a builder's stock plan, construction

starts on time, the customer supplied labor, and the customer specified one or more subcontractors.

b.) One factor that may negatively affect customer satisfaction is the customer utilizes the builder's custom design/build option.

The results of this study show that some construction-scheduling factors very likely affect customer satisfaction. These factors should be important to contractors, because high levels of customer satisfaction should result in new and repeat customers. One of the factors that probably affects customer satisfaction is a factor that contractors have substantial control over: construction is finished on time. Therefore, contractors should prioritize activities that are designed to minimize construction delays, especially those that may cause the project to be completed behind schedule.

Appendix A – Customer Survey

General Information

1. Please describe the structure that you have had built recently.

   Size_____

   Primary usage_____

   Unique features_____

   _____

   General Contractor_____

2. Was it pre-manufactured? Yes No

   If so, by what company?_____

3. Did you supply any labor or agree to do any of the work that was necessary to complete this project? Yes No If so, what tasks did you perform?_____

   _____

4. Did you specify or hire any subcontractors to do any of the work that was necessary to complete this project? Yes No

   If so, what tasks did these subcontractors perform?_____

   _____

5. How were the plans for this building produced? (Check all that apply)

   ___ Used builder's stock plan

   ___ Utilized the builder's custom design/build option

   ___ Copied/modified the design of another facility

   ___ Obtained/developed plans from someone other than the builder

Scheduling

(**Note:** Dates may be given to the nearest week.)

6. Before you decided on the builder for the project, did you have a starting date in mind? Yes No

   If so, what was your desired starting date?_____

7. Did the builder discuss a starting date with you before you made an agreement with that builder? Yes No

   If so, what starting date was proposed?_____

8. Before you decided on the builder for the project, did you have a project deadline in mind? Yes No

   If so, what was your desired completion date?_____

9. Did you discuss a completion date with the builder before making an agreement with that builder? Yes No

   If so, what completion date was agreed upon?_____

10. Describe any schedule-related penalties or incentives written into the contract for this building._____

    _____

11. On what date did the builder actually begin construction?_____

12. On what date did the builder finish construction?_____

13. If there were delays, what caused them?

    (Briefly describe each that applies)

    Weather_____

    _____

    Labor availability_____

    _____

    Equipment problems_____

    _____

    Material availability_____

    _____

    Approval of permits, inspections, plans_____

    _____

    Unspecified builder delays_____

    _____

    Unspecified subcontractor delays_____

    _____

    Other_____

    _____

14. If there was a delay in completing construction of the building, did the delay add to the cost of the building, either directly or through lost income?

Yes No If so, briefly describe how you believe building cost was increased or income was lost._____

15. Were you satisfied with the progress made during construction of this building?
Yes No Please explain._____

16. Looking back, what, if anything, could you have done to improve the timeliness of the project?_____

Appendix B – Results

*Note that some "total percentages" add to more than 100% when more than one response could be indicated (i.e. choice questions).

Table B1. Building sizes of 24 customers who responded to the survey (in square feet)

	All buildings	Equipment storage	Livestock	Multiple-use
Average	8,270	3,200	15,360	18,480
Maximum	47,000	4,860	44,780	47,000
Minimum	600	600	1,150	3,840

Table B2. Primary use of building

	Number	Share of total (%)
Equipment storage	6	22.2
Livestock	18	67.7
Multiple-use	3	11.1
Total	27	100.0

Table B3. Use of premanufactured buildings

	Number using	Number not using
Premanufactured buildings	3	24

Table B4. Use of customer supplied labor

	Number using	Number not using
Customer supplied labor	22	5

Table B5. Use of customer specified or hired subcontractors

	Number using	Number not using
Specified or hired subcontractors	14	13

Table B6. Method of designing building plan

Variable	Number	Share of total (%)
Builder's stock plan	6	22.2
Builder's design/build option	11	40.7
Copied/modified existing building	11	40.7
Other sources of information/plans	11	40.7
Total	39	144.3

Table B7. Schedule-related dates

Variable	Number	Share of total (%)
Customer had desired start date	22	81.5
Builder proposed start date	25	92.6
Customer had desired completion date	18	66.7
Builder proposed completion date	20	74.1

Table B8. On-time performance on projects

	Number	Share of total (%)
Project started on time	13	61.9
Project completed on time	12	66.7

Table B9. Delay in construction added to building cost

	Number yes	Number no
Additional building cost	30.0	70.0

Table B10. Customer satisfaction with progress during construction

	Number satisfied	Number not satisfied
Customer was satisfied	84.6	15.4

Appendix C – Effects of Other Variables in Regression Analysis

Several variables were eliminated in the regression analysis, due to poor p-values. While they were not statistically significant, it is worth noting how they affected on-time performance, though these should be interpreted with caution. The effect is based on the value of the parameter estimate.

Positive effect	Negative effect
Premanuf.	Labor
Subcontractor	Other source
Stock plan	Desired completion
Design build	
Desired start*	
Actual start	
Actual completion**	
On-time start	

*Parameter estimate = 0
**No parameter estimate computed

Conclusion

Scheduling is an important aspect of any building project, because it is the timeline for construction. Scheduling mistakes can affect an entire project, in terms of cost, quality, and customer satisfaction. The authors evaluated problems and practices in construction from the perspectives of contractors and customers. The contractor's point of view was assessed on the basis of on-time performance, while the customer's point of view was assessed on the basis of satisfaction with construction progress. While each viewpoint was examined separately, they are interconnected. Because on-time project completion probably improves customer satisfaction with construction progress, steps to improve on-time performance cannot be ignored by contractors. Customer satisfaction often results in new and repeat customers. For this reason, contractors should strongly consider those practices and factors that improve on-time performance. They should also consider those factors that improve customer satisfaction with construction progress. This should result in more successful scheduling practices, more satisfied customers, and a successful company.

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